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OBSERVATIONS AND EPHEMERIDES OF THE VARIABLE STAR *Y CYGNI.*

By N. C. DUNÉR.

THE manner in which I determined the first elements of the orbit of the Algol star *Y Cygni*, together with the numerical values of the elements as computed from the minima of the years 1886 to 1898, have been published in the ASTROPHYSICAL JOURNAL, **11**, 175–191, 1900. The following even and odd minima of the star were observed[1] during the autumn of 1900

Epoch	Minimum (Gr. M. T.)					O.—C.	Observer
3356	1900	Sept.	15^d	9^h	33^m	−13^m	D
3370		Oct.	6	9	8	− 1	B
3392		Nov.	8	8	1	−11	D
3400			20	7	49	− 2	B
3410		Dec.	5	7	26	0	B
3416			14	7	11	+ 1	B
3422			23	6	41	−13	D
3491	1901	April	5	10	38	−24	D
3495			11	10	46	− 4	D
3503			23	10	5	−23	D
3505			26	10	12	−11	D
3507			29	9	57	−21	D

[1] The minima in 1900 published in *A. N.* No. 3720 are corrected for the equation of light, which is not the case with the observations below.

and spring of 1901 by myself and Dr. Bergstrand, now second astronomer at this Observatory. I have added the difference between the calculated and the observed dates.

From these observations we obtain the following two normal minima and normal deviations.

Epoch	Normal Minimum	O.—C.
3396	$1885.0+5431^d.331$	$-0^d.004$
3501	$1885.0+5588.426$	-0.012

These normal minima have been computed from 1885.0, in agreement with the principal epoch t_0 but in contrast to the earlier ones. It will be seen that these normal minima, which were unknown in the derivation of the elements, agree better with them than do several of the normal minima employed. Under these circumstances I have not thought it yet necessary to attempt the correction of the elements, but have merely computed the following ephemeris for 1902.

Even Minima						Odd Minima					
Epoch	Minimum (Gr. M. T.)					Epoch	Minimum (Gr. M. T.)				
3676	1902	Jan.	7^d	19^h	19^m	3675	1902	Jan.	6^d	3^h	7^m
3696		Feb.	6	18	24	3695		Feb.	5	2	16
3716		Mar.	8	17	30	3715		Mar.	7	1	25
3736		April	7	16	35	3735		April	6	0	34
3756		May	7	15	40	3755		May	5	23	23
3776		June	6	14	46	3775		June	4	22	53
3796		July	6	13	56	3795		July	4	22	2
3816		Aug.	5	12	56	3815		Aug.	3	21	11
3836		Sept.	4	12	0	3835		Sept.	2	20	20
3856		Oct.	4	11	5	3855		Oct.	2	19	30
3876		Nov.	3	10	11	3875		Nov.	1	18	39
3896		Dec.	3	9	16	3895		Dec.	1	17	48
3916			33	8	20	3915			31	16	58

During the observations in 1900 and 1901 the duration of the even minima was considerably longer than that of the odd minima, whence it now appears almost certain that there is hardly any further justification for the doubt expressed at several places in the article referred to as to the correctness of my assumption that the principal epoch in 1885 coincided with the perihelion passage. In general, the elements therefore appear to be correct in this respect also.

Upsala, July 1, 1901.

PECULIARITY OF FOCAL OBSERVATIONS OF THE PLANETARY NEBULÆ AND VISUAL OBSERVATIONS OF *NOVA PERSEI* WITH THE FORTY-INCH YERKES TELESCOPE.

By E. E. Barnard.

As is well known, and as I have shown further in *Monthly Notices of the Royal Astronomical Society*, Vol. LX, January, 1900, pp. 255–557, the focus of a large refracting telescope for the planetary nebulæ is something like 0.25 inch farther away from the object-glass than for a fixed star. With a high power on the 40-inch Yerkes telescope this difference of focus for a star and a gaseous nebula is very striking. It is so decided that if one should first focus carefully on a star and then examine a planetary nebula with the same adjustment, he would see only the coarser details. A re-focusing on the nebula would reveal details he would not ordinarily suspect. This also holds in photographing these bodies, so that a focus which (with a color-screen) would give a perfect image for a star with the 40-inch would not clearly show the details of a planetary nebula. By setting the plate from a quarter to a third of an inch farther out than for the star the details of the nebula are beautifully shown while the stars are but ill-defined, and the fainter ones entirely lost.

This peculiarity of a refracting telescope is a natural consequence of the difference in the spectra of the stars and the planetary nebulæ, as has been pointed out to me by Professor Hale.

It may be interesting to copy here the table showing these differences of focus printed in *Monthly Notices*, Vol. LX, to which are added several other objects and more observations. These were all determined with the 40-inch.

TABLE OF FOCUS FOR THE PLANETARY NEBULÆ.

N. G. C.	α 1860.0	δ 1860.0	Neb.—Nucl.	Neb.—Star.	Nucl.—Star.
			in.	in.	in.
1535	$4^h\ 7^m\ 44^s$	$-13°\ 6'$	+0.23	+0.28	+0.05
2392	7 20 53	+21 12	+0.29	+0.32	+0.03
3242	10 18 2	−17 56	+0.12	+0.10	+0.04
6543	17 58 36	+66 38	+0.16	+0.21	+0.05
6720 (*M* 57)	18 48 23	+32 51	+0.20	+0.30	+0.10
6826	19 41 2	+50 11	+0.22	+0.21	−0 01
6905	20 16 9	+19 40	+0.19	+0.33	+0.15
7009	20 56 33	−11 55	+0.19	+0.23	+0.04
7662	23 19 11	+41 45	+0.06	+0.20	+0.14
			+0.18	+0.25	+0.06

No. 1535 — Two nights' observations.
2392 Seven " "
3242 Five " "
6543 Two " "
6720 Two " "
6826 Two " " for nucl.—star, both the same.
6905 Two " "
7009 Two " " for neb.—star.
7662 Four " " " " "

The *Orion* nebula gave nebula − star = + 0.22 inch.

Nova Aurigae is a striking example of this peculiarity. Recent observations with the 40-inch show that it has declined in the past few years to the thirteenth magnitude. With as faint an object as this the difference of focus between it and a star is decided, the *Nova* being best seen with a focus about one-third inch farther out.

This is shown by the following observations for focus on Nov. 3, 1900:

	in.	
Focus on *Nova Aurigae* - -	2.43	(3 obs.)
Focus on star - - - -	2.16	(3 obs.)
Nova—star - - -	+0.27	

From the above table it would appear that if a planetary nebula were so minute as to present no appreciable disk in the telescope its nebulous character should still be recognizable without the spectroscope by this peculiarity in its focus.

No. 7662 has been observed quite a number of times with the micrometer for position of its nucleus. Sometimes the central star was very faint and difficult, while at other times, apparently as favorable, it has been an easy object. This has led me to suspect it of variation, but I have not yet been able to confirm the supposed variability.

In some respects No. 2392 is the most remarkable of these objects as seen with the great telescope, in which it is very beautiful. The following description, with some changes, is from *Monthly Notices*, LX, for January, 1900:

A bright star of the ninth magnitude in (but not exactly central) a brightish ring which is oval in form and almost incomplete in its southern part. This ring, which is well defined inside and out, is surrounded by a vacuity, and this in turn by a broad ring of light less intense than the inner ring, and with a distinct break in it north preceding. This ring breaks up into a clouded or unequal surface, and is very irregular on its inner edge but fairly uniformly circular on the outside. The inner ring is filled with nebulous light, which has a bright spot in it south preceding the nucleus. I have found another excessively difficult star within the inner ring north of the bright star; this minute object comes to a focus with the nebula and not with the central star. It is therefore, doubtless, a small condensation of the nebula not so far advanced in stellar condition as the bright central star. When the atmospheric conditions permit, this beautiful nebula is best seen with a very high power — it stands magnifying well. It must also be very carefully focused — on the nebulosity itself — before the details described are seen. With a low power it is quite different, for it then appears as a bright yellowish star in a circular disk of light, surrounding which is a perfectly circular vacuity, and surrounding this vacuity is a symmetrical circular ring not so bright as the central disk. This, I suppose, is the general impression it gives when examined casually. But with the higher powers it loses much of this symmetry and becomes more complex, as already described.

In the article referred to in *Monthly Notices*, LX, the faint additional star in the central ring is described as being south of the central star. It is north.

The focus determinations for this nebula are the best of any in the list, as they depend on seven nights' observations.

In No. 6905 the central star is faint, and there is not much detail to focus on. A note says: "there seems to be some detail in the nebula, possibly spiral in form, but mainly an inequality of its light."

This brings me to the purpose of this note, some peculiarities of *Nova Persei*. I was absent with the eclipse expedition to Sumatra when this star appeared, and did not see it during its great brilliancy. It had declined to the sixth or seventh magnitude when I first saw it in August. Like its predecessors, it shows, in the fading of its light, the nebular spectrum, and seems, therefore, to have become a gaseous nebula.

To test the nebulous character of this object visually I have carefully examined it with the 40-inch, both for nebulosity and for peculiarity of focus. I have not been able with certainty to see any nebulosity. A careful series of focus readings on two dates, comparing it with the white star *DM.* $+43^{\circ}732$ (7.5 magnitude; 1855.0: $3^{h}\,18^{m}\,45^{s}+43^{\circ}\,14'.6$), does not show any difference in focus between the star and the *Nova*.

Following are the measures for focus:

1901. August 12. *Nova*, . . 2.25 in. (4 obs.)
7.5 mag. star, 2.26 in. (4 obs.) } power 700

Nova − 7.5 mag. star = − 0.01

1901. September 3. *Nova*, . . 2.29 in. (5 obs.)
7.5 mag. star, 2.30 in. (5 obs.) } power 1300

Nova − 7.5 mag. star = − 0.01

This difference, though it is the same in the two sets of observations, doubtless does not mean anything. The readings are on a scale of inches engraved on the tube. The tube lengthens and shortens with changes of temperature, which causes the difference in the two sets of readings.

This, of course, does not necessarily imply the absence of nebulosity in the *Nova*. It may mean that the visual light is so predominant as to mask the usual effect produced by a nebula in its focus. Its action is therefore more like that of the nucleus of a planetary nebula. When the *Nova* has faded greatly it will be interesting to see if its focus becomes like that of the planetary nebulae.

On August 12 the seeing was unusually good. Examining the *Nova* with high powers, I was struck with its appearance. It was brighter than the star, but under the high magnifying powers its light was strikingly dull, having more the appearance of planetary light. This was so decided that had I been examining the stars in that region I should at once have singled out the *Nova* as different from any of the stars. The spurious disk appeared much duller and somewhat larger than that of a star, and of a slight yellowish color.

This peculiarity has been seen several times since.

On several occasions a faint companion has been visible north following *Nova Persei*. On September 16 and 23, 1901, its position was measured.

NOVA PERSEI AND *a*.

1901.709	63°.5	Dist. 19″.6
.729	66.8	19.2
1901.719	65.1	19.4

It is about 15^m and very difficult to measure.

Five other stars of about the thirteenth magnitude were also measured.

NOVA PERSEI AND *b*.

1901.578	116°.21	102″.55	13 mag.
.693	116.14	102.57	
.709	116.33	102.50	
1901.66	116.23	102.54	

NOVA PERSEI AND *c*.

1901.578	211°.20	124″.25	13 mag.
.693	211.34	124.20	
.709	211.28	124.18	
1901.66	211.27	124.21	

NOVA PERSEI AND *d*.

1901.732	303°.48	164″.62	13 mag.
.749	303.67	165.03	
.751	303.62	165.25	
1901.74	303.59	164.97	

NOVA PERSEI AND *e*.

1901.732	63°.07	158″.55	12.7 mag.
.749	63.10	158.76	
.751	63.07	158.51	
1901.74	63.08	158.61	

NOVA PERSEI AND *f*.

1901.732	292°.98	181″.70	12.8 mag.
.749	293.07	181.82	
.751	293.02	181.78	
1901.74	293.02	181.77	

All the observations, except for *a*, are double distances.

On September 16 at 14^h the *Nova* was carefully compared in brightness with the stars *DM.*+43°.720, *DM.*+43°.730, and *DM.*+43°.732. The result for the *Nova* was 7.3 magnitude on the *DM.* scale of magnitudes.

Having seen the announcement by M. Flammarion and Dr Max Wolf of the discovery of a nebula about *Nova Persei* I carefully looked for it with the 12-inch refractor on the night of September 20. The following note was made:

> Examined *Nova Persei* between 13^h and 14^h with the 12-inch, using a low power (about 90 diameters). I could not see with certainty anything of the nebula encompassing this star as described by Dr. Max Wolf in *A.N.*, 3736. The sky and seeing were good with the low power. The region of the *Nova* for some distance seemed to have more scattered light than that farther away, while the region of the 7.5 mag. star *DM.*+43°.732, about 2½ minutes preceding and 10′ south, by contrast was free of this peculiarity.

I have since that date examined the *Nova* with the 40-inch for the nebulosity after having seen Mr. Ritchey's excellent photograph of it. Knowing the exact positions of the various parts of the nebula, these were perhaps seen, but the night was not sufficiently pure to make certain of it. This nebulosity is,

of course, vastly better suited for the photographic plate than for visual observations with any telescope.

During the observations of *Nova Persei* a nebula was found which from its proximity to the new star is worthy of record. It lies one degree south of the *Nova*.

This nebula was measured with reference to a twelfth magnitude star.

TWELFTH MAGNITUDE STAR AND NEBULA.

1901.735	4°.7 (3)	33′.9 (2)

The twelfth magnitude star was measured with reference to the 7.8 mag. star *DM.*+42°.776 whose place for 1855.0 is

$\alpha = 3^h\ 22^m\ 25^s.5\ \ \delta + 42°\ 15'.2$

Twelfth mag. star precedes 7.8 mag. star $0^m\ 55^s.69$ (14)
" " " north of 7.8 " " 1′ 55″.61 (2)

This gives for the position of the nebula

1860.0 $\alpha = 3^h\ 21^m\ 50^s.5\ \ \delta = +42°\ 18'.7$

It is about 13.5 mag., a half minute in diameter and somewhat brighter in the middle; and is perhaps irregular in form.

YERKES OBSERVATORY,
September 13, 1901.

NOTE.—A photograph of the spectrum of *Nova Persei*, taken on September 24 by Mr. Walter S. Adams with a one prism spectrograph attached to the 24-inch reflector of the Yerkes Observatory, indicates that the continuous spectrum in the yellow and green is relatively stronger than in the case of the planetary nebulae. This may perhaps be sufficient to account for the peculiarities of focus observed by Professor Barnard.— ED.

OBSERVATIONS OF THE EARLIER SPECTRUM OF *NOVA PERSEI.*

By WALTER S. ADAMS.

THE photographic study of the spectrum of *Nova Persei* was commenced at the Yerkes Observatory by Mr. Ellerman on February 24, and continued when weather permitted until May 1, at which date the spectrograph was dismantled preparatory to being adapted for work with a reflecting telescope. Of the series of plates thus obtained rather more than one-half were photographed with a dispersion of three prisms, and hence are comparatively limited in their range, and better suited for the detailed study of the structure within individual lines than for the direct determination of wave-lengths. The remaining plates were secured with a one prism spectrograph attached to the 40-inch refractor, and cover in general the extent of spectrum from D to λ 3700. Seventeen of these have been measured in whole or in part, and it has seemed best to give a summary of the results found, without in this place entering into minute details, or considering the conditions necessary in the star to give rise to the extraordinary variations observed. All of the plates measured were obtained by Mr. Ellerman, who was assisted in guiding, at times a task of no little difficulty on account of the low altitude of the star, by Mr. Sullivan.

A statement of the changes which occurred in the spectrum of *Nova Persei* up to April 8 has already been published.[1] Since that time it has varied between two general types. The first, which Pickering[2] calls the normal, and which seems to coincide with the periods of greatest brightness of the star, has a relatively strong continuous spectrum, and the hydrogen lines in their normal positions. The second type is characterized by

[1] ASTROPHYSICAL JOURNAL, 13, 238, April, 1901.

[2] *Harvard College Observatory Circular* No. 59. See also Sidgreave's paper: *The Observatory*, Vol. XXIV, No. 305, May, 1901.

a relatively weak continuous spectrum, the great strengthening of various bright lines, and the lateral extension and hence apparent displacement of some of the hydrogen lines. In addition to these broad variations there are many minor ones, some of which appear to depend upon the type of spectrum present, others to be quite independent of it. The more important of these variations will now be considered in detail.

I. VARIATIONS IN THE BRIGHT HYDROGEN LINES.

Hι is clearly visible upon one of the earlier plates at λ3771. In the general falling off of intensity in the ultra-violet, however, it soon becomes too faint for measurement, and then disappears.

Hθ has been measured upon three of the early plates, giving a wave-length 3800.

Hη is shown upon the plates of February 25 to be accompanied by a bright band upon its less refrangible side. On February 27 this has united with *Hη* to form a single band with center at λ3846, and remains in this position so long as the band is visible at all.

Hζ is probably the most remarkable line in the entire spectrum. After remaining constant in position and width until March 15, it suddenly adds a broad violet component in the interval between March 15 and 22, thus greatly increasing its normal width. At the same time, however, its red edge begins to decrease in intensity, the loss continuing while the violet edge remains constant until the original width is nearly reached. The result is a very great displacement of the center of the line toward the violet, amounting in full to over twenty tenth-meters. It seems probable that in this new position the line is not *Hζ* at all, but belongs to some new element, perhaps helium, which has a strong line at λ 3888.8. The fact remains, however, that upon two plates, those of April 8 and 18, in which the type of spectrum seems to have returned to the normal, *Hζ* is seen in its original position, and apparently of its original width, although the band is too weak to admit of measurement.

The following table gives the position of the center, and of

the violet and red edges of $H\zeta$, together with its width in tenth-meters.

Date	Center	Violet edge	Red edge	Width int.m.	
February 27–March 15... .	3894	3877	3911	34	7 plates
March 28	3881	3855	3907	52	1 plate
April 3	3879	3855	3905	50	2 plates
April 15–17	3874	3855	3893	38	2 plates

A sequence of order of brightness among the other hydrogen lines seems to be maintained upon the earlier plates. By April 4, however, $H\gamma$ has become fully as strong as $H\beta$, and appears to continue so throughout the remainder of the observations. In general it may be said that upon plates which exhibit the peculiar type of spectrum the bright hydrogen lines show a much more nearly uniform intensity than upon plates where the spectrum is normal. In view of the gradual falling off of intensity in the ultra-violet this fact is somewhat remarkable.

In addition to intensity changes there are variations in the shadings of several of the hydrogen lines, particularly $H\delta$ and $H\gamma$. The photographs of February 27 show $H\delta$ to fall off very gradually toward the red owing to its union with a bright shade whose red edge falls at λ 4146. This shade begins to decrease in intensity, and by March 22 has become incapable of measurement, thus leaving the red edge of $H\delta$ comparatively sharp. In distinct contrast to the behavior of $H\delta$ is that of $H\gamma$. Until March 22 its red edge remains fairly distinct; on March 22 there are traces of a faint bright shade forming close to its red edge, and on March 28 this has united with $H\gamma$, giving a very broad and strong band whose red edge falls at λ 4391. This band appears to be a further characteristic of the peculiar type of spectrum, as it appears upon all plates showing such a spectrum, while on the plates of April 8 and 18 it is absent, or, at any rate, very greatly weakened. A maximum in this red component of $H\gamma$ falls at λ 4387, and is probably the line observed by Pickering at λ 4384.

II. VARIATIONS IN THE DARK HYDROGEN LINES.

On February 24 the dark hydrogen lines are visible as faint diffuse shades on the more refrangible side of the bright bands. These are hardly to be seen on February 27, but from that time appear to increase in intensity. Upon the plates of February 28 they are clearly visible, particularly $H\delta$ and $H\gamma$, and by March 4 have become strong, with $H\delta$ showing traces of being double. The greatest intensity seems to be reached on March 11, when all the lines are very prominent and are double, with the distance between the components increasing toward the violet with the increasing dispersion. The more refrangible component then begins to weaken, the difference of intensity showing clearly upon the plates of March 15. On March 22 this component has entirely disappeared, and the less refrangible one has become much fainter. Finally by March 28 both components have vanished, and the bright hydrogen lines are joined with the faint bright bands hitherto separated by these dark lines, thus giving an uninterrupted shading to the violet.

III. VARIATIONS IN K.

The earliest plates show K as a broad bright band of about the same intensity of $H\epsilon$, and slightly more intense than $H\zeta$, with a prominent maximum at λ 3937, and a faint dark line on the more refrangible side of this. The dark line appears to follow the behavior of the dark hydrogen lines, increasing in strength until March 11, when it is a noticeable feature of this part of the spectrum, and then gradually fading, until on March 22 it has become invisible. The bright band upon which it is projected, after remaining fairly constant until March 11, also follows the course of the dark hydrogen lines, and has become extinct on March 22. This fact has already been noted by Sidgreaves.

IV. VARIATIONS IN BANDS λ4928 AND λ5020.

The intensity of these two bright bands, besides being greatly influenced by the general falling off in the spectrum to the red of $H\beta$, also exhibits considerable relative changes. Of nearly

equal strength on February 24 they continue approximately so until the change of spectrum occurs between March 15 and 22. After this change λ5020 is much brighter than λ4928, although both have become greatly weakened in absolute intensity. This weakening is so great that after March 28 little more than traces of λ4928 can be seen, while upon plates showing the normal spectrum, that is, those of April 8 and 18, λ5020 also disappears.

In addition to changes of intensity, however, there occurs what appears to be a displacement of the center of λ5020 by some 12 tenth-meters toward the violet. As in the case of $H\zeta$ this probably takes place through addition of an extension on the violet edge, and a contraction of the red edge, but here the two processes seem to be much more nearly synchronous, as is shown by the comparatively slight changes in width.

The following table illustrates this fact:

Date	Center	Violet edge	Red edge	Width	
February 28–March 6.....	5022	5004	5041	37	7 plates
March 15.....	5019	5000	5036	36	1 plate
March 28.....	5013	4993	5034	41	1 plate
April 3–26.....	5010	4989	5033	44	4 plates

V. VARIATIONS IN *b*.

The earliest plates of the series show *b* as a strong band comparable with $H\gamma$ in brightness. It begins to fall off rapidly, however, and on March 15 is but little brighter than λ5020. On March 28 barely a trace is visible, and after that date it is not seen.

VI. VARIATIONS IN THE REGION λ4470 TO λ4740.

This part of the spectrum probably exhibits more variations than any other, both as regards intensity and position of the lines. Previous to the general change of type it may in general be said to consist of three very broad bright bands lying against a strong background of continuous spectrum. These bands extend from λ4468 to λ4686, and are divided by narrow dark breaks at λ4529–4537 and λ4604–4615. Beyond λ4686

occur various slight shades and maxima, notably a maximum at λ4721, but their study is difficult on account of the great intensity of the plate in this region. The three bands begin to break up, however, even before the main change of spectrum takes place. A dark break forms at λ4484–4504, and a maximum at λ4575. Furthermore, as early as March 4 there are traces of the formation of an extension upon the violet edge of λ4470. This remains comparatively faint until the change of type occurs, then increases very greatly in intensity, and, joining the adjacent shade, makes up a bright band extending from λ4456 to λ4491, and probably representing the helium line λ4472. On March 28 this band is fully as strong as *Hε*. A faint shade is present at λ4505–4544, and a somewhat stronger one at λ4556–4590, with a maximum at λ4563. A remarkable feature of this last shade is the displacement of its red edge from λ4604 to λ4590. The agreement of this displacement of 14 tenth-meters with that of 12 tenth-meters on the violet edge of λ4470 (from λ4468 to λ4456) would almost seem to argue for a connection between the two.

At the same time that these changes take place among the more refrangible bands the band λ4615–4686 begins to break up and extend. A dark break forms at λ4659 and extends as far as λ4672, while a faint shade upon its red side gradually increases in intensity until, with the remaining portion of the original bright shade, it forms a strong band extending from λ4672 to λ4743, and having an intense maximum at λ4689. The three bands λ4456–4491, λ4615–4659, and λ4672–4743 are the most striking features of this part of the spectrum of the later type, and vary considerably in intensity. On March 28 they are all about equal; on April 3 λ4615–4659 is the strongest of all. The first of the three, λ4456–4491, then seems to lose in intensity, and does not again become equal to either of the other two. On several plates, particularly those of April 29 and May 1, these two are about equally intense, and fully as bright as *Hγ* or *Hβ;* that is, are among the brightest bands in the entire spectrum. It should be noted of band λ4672–4743 that its composite

character is noticeable upon several plates, the darkening between its parts showing especially clearly on the plates of April 22 and 24.

In addition to this discussion of the lines which occur on nearly all the plates, mention may be made of a few which have been seen upon but one or two. Of these a bright band with a center estimated at λ4960 is the most important. It makes its appearance upon a plate taken April 19, and is fairly prominent upon one of April 25. Unfortunately the series of photographs ends too early to admit of following its course very far. It is probably the nebula line λ4959. The dark line noted by Pickering at λ3865 is seen on a plate of April 8. I may also call attention at this point to a possible slight displacement of the center of *Hε* which seems to occur at the time of change of spectrum between March 15 and 22. The mean of seven plates

No. of plates	Part of line	λ	Substance	Remarks
3		3800	*Hθ*	
6		3846	*Hη* + (?)	Center of band formed by union of *Hη* and another band
2		3874	*Hζ*	See Section I
2		3879		
1		3881		
7		3894		
7		3935	*K*	
7	Maximum	3937		
7		3973	*Hε*	
6		3970		
3	Maximum	3973		
6		4029	*He*	
5		4067		
15		4105	*Hδ*	
7	Red edge	4146		Perhaps the red edge of the *He* line λ4121
8		4179		
9		4235	*Fe* (?)	

No. of plates	Part of line	λ	Substance	Remarks
8		4300		
14		4345	*Hγ*	
6		4382		
3	Maximum	4387	*He*	
3		4408		
8		4474	*He*	See Section VI
7	Violet edge	4468		There is a slight dark break at λ 4484–4504
4	Red edge	4529		
4		4524		
3	Maximum	4563	*Ti* (?)	
6		4573		
4	Maximum	4575		
7	Red edge	4604		
13	Violet edge	4615		
3		4636		See Section VI
4	Red edge	4686		
2	Maximum	4689		Perhaps the nebula line
4		4707		
3	Maximum	4721	*He* (?)	
4		4820	*Fe* (?)	
14		4864	*Hβ*	
4	Red edge of maximum	4917	*He*	
10		4928		
4		5010		
1		5013	*He*	See Section IV
1		5019		
7		5022		
10		5174	*Mg*	
3		5237	*Fe* (?)	
3		5277		
8		5319	*Fe*	

previous to the first date gives as the center of this band λ3973: the mean of six plates after the second date λ3970. The disappearance of the dark hydrogen lines may, however, influence these measures somewhat.

In the above table are given the wave-lengths of bright lines measured upon three or more plates, together with some of the most probable identifications. The number of plates measured is given in the first column, and the part of the line to which the wave-length refers in the second column. When no statement is made the center is understood.

The comparison spectrum employed in all of these measures is that of titanium. Several lines lying to the red of those given might be added, but their wave-lengths would be subject to considerable errors of extrapolation, and hence it has seemed best not to include them in the table.

YERKES OBSERVATORY,
July, 1901.

PLATE VII.

FIG. 1.—PHOTOGRAPH MADE WITH TWO-FOOT REFLECTOR.

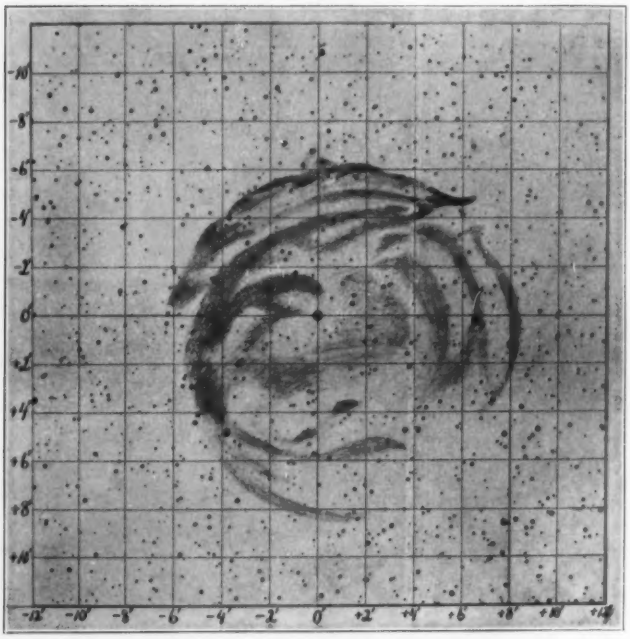


FIG. 2.—DIAGRAM FROM ORIGINAL NEGATIVE.

NEBULOSITY AROUND *NOVA PERSEI.*

By G. W. RITCHEY, Yerkes Observatory.

NEBULOSITY ABOUT *NOVA PERSEI.*

By G. W. RITCHEY.

On the night of September 20, 1901, the region of *Nova Persei* was photographed with the two-foot reflecting telescope of this Observatory, and a fairly satisfactory negative of the spiral or annular nebula surrounding the *Nova* was obtained.

The telescope mirror has a focal length of 93 inches, and on this occasion an aperture of 22 inches was used, so that the ratio of focal length to aperture was nearly as 4¼ to 1. The silver surfaces of the large mirror, and of the flat, are nearly new and are in fine condition. The night was fairly, but not extremely, transparent. A Cramer "Crown" plate was used, of sensitiveness nearly twice as great as the average for such plates, and an exposure of three hours and fifty minutes was given. With these favorable conditions and with the great concentration given by the short focus mirror the image of the nebula on the negative is very faint; only the streamer or wisp to the south of the *Nova* is strong; this part of the nebula was photographed earlier by Dr. Max Wolf.[1]

The reflector photograph is free from the false penumbra about the *Nova* which is shown on photographs of this object obtained with refracting instruments. The image of the *Nova* in the reflector negative with nearly four hours' exposure is about 20″ in diameter and there is little or no halo of nebulosity immediately about it; two moderately dense wisps of nebulosity, however, extend from the *Nova* toward the west, curve toward the north, and merge into the convolutions of the nebula. As will be seen from the accompanying illustrations, Plate VII, the nebula is of quite complex form; whether it is spiral or consists of several annuli with interlacing branches cannot now be stated; possibly a stronger negative may make this clear.

[1] *A. N.*, 156, 254.

The greater part of the delicate structure shown on the negative is so faint that there was no hope of being able to reproduce this well in the half-tone plate. Accordingly a diagram was hastily prepared which shows the approximate position of nearly all of the faint nebulosity visible on the negative. The positions of the coördinate lines with reference to the stars in the diagram are only roughly approximate. The enlargement as compared with the original negative is about five diameters.

YERKES OBSERVATORY,
September 26, 1901.

NOTES ON VARIABLE STARS.

By J. A. PARKHURST.

THE forthcoming publication of a new catalogue of variable stars by the commission appointed by the *Astronomische Gesellschaft*, is the occasion of the following preliminary report of observations made with a 6½-inch reflector and the 12- and 40-inch refractors of the Yerkes Observatory. The final reduction is reserved till the completion of the work, now in progress, of finding the photometric magnitudes of the comparison stars. The approximate magnitudes here assigned are based on the assumption for the limits of the apertures used, of 12.8 magnitude for the 6½-inch; 14.0 magnitude for the 12-inch, and 17.0 magnitude for the 40-inch. The notation of Dr. Chandler is followed; for stars not in the *Third Catalogue* the provisional number, in parenthesis, being one-tenth the Right Ascension for 1900, expressed in seconds of time. The dates of maxima and minima are only roughly indicated, the more definite determination being reserved for the final reduction. This report is a continuation of those in the *Astronomical Journal*, **21**, 11, and the ASTROPHYSICAL JOURNAL, **12**, 52.

103. *T ANDROMEDAE.*

Minima were passed late in December, 1899, and early in October, 1900. The magnitude at minimum was about at the limit of the 6½-inch, but an examination of the field with the 40-inch showed no stars liable to be mistaken for the variable when faint, those nearer than 4′ being of the fourteenth magnitude or fainter. The variable was not far from maxima in May, 1900, and February, 1901. These data result from twenty-eight observations.

243. *U CASSIOPEIAE.*

This star faded from the tenth to below the fourteenth magnitude between 1898, June 27 and August 17; also from the

eleventh to the fourteenth magnitude between 1900, January 21 and February 22; but the observations, nine in number, do not suffice to fix the minimum in either case.

267. *V ANDROMEDAE.*

After the minimum reported in this JOURNAL, **12**, 52, the variable passed a maximum at the ninth magnitude in May, 1900, and a minimum at the fourteenth magnitude in October of the same year.

294. *W CASSIOPEIAE.*

A maximum at 8½ magnitude was passed in December, 1899, and a minimum about the twelfth magnitude, in June, 1900.

466. *U PISCIUM.*

This star was twelfth magnitude, 1900, January 21, and had faded to less than fourteenth magnitude when last seen, February 22. There were no stars brighter than the fourteenth magnitude noticed with the 40-inch, within less than 2′ of the variable.

659. *X CASSIOPEIAE.*

This intensely red star (spectral type III, b; Dunér) remained with slight fluctuations near the twelfth magnitude during 1899, and passed a poorly defined maximum about the tenth magnitude in February or March, 1900. As there are forty well-distributed observations during this period the presence of any considerable minor maxima or minima is rendered very doubtful.

678. *U PERSEI.*

Minima were passed, a little fainter than the twelfth magnitude, late in December, 1899, and early in November, 1900; also a seventh magnitude maximum in May, 1900.

(787)—*ANDROMEDAE.*

The discovery by Anderson was announced in *A. N.*, **147**, 175. The position, found by micrometer comparisons with *Bonn A. G. Cat.*, 1887 and 1939, is—

R. A. $2^h\ 8^m\ 24^s.7$, Decl. $+43°\ 37'\ 46''$ (1855)
11 14.1 50 26 (1900)

A chart of the neighboring stars brighter than the thirteenth magnitude will be found in *Popular Astronomy*, **8,** 162.

My first observation was 1899, February 6, when the variable was found at 10.0 magnitude. It faded steadily, passing below the limit of the 6½-inch in April, and remaining invisible in that instrument till August 30, when it was found at 12.0 magnitude. It then increased in light and passed a maximum at 7.0 magnitude about the first of December, 1899. The following minimum, at 14.0 magnitude, the last of July, 1900, was observed with the 12- and 40-inch telescopes.

(1922)—*AURIGAE.*

Discovered by Madam Ceraski (see *A. N.*, **147,** 15). The position found by micrometer comparisons with *DM.* + 36° 1141 (place from the Lund Zones) is—

R. A. $5^h\ 17^m\ 6^s.0$, Decl. + 36° 46′ 11″ (1855)
20 8.6 48 53 (1900)

After the minimum reported in this JOURNAL, **12,** 54, it was found at the tenth magnitude in August, 1900, and at 11.5 magnitude in February, 1901. The identification in its faint stages presents no difficulty, a wide pair of fifteenth magnitude stars 1′ south aiding materially.

2013. *U AURIGAE.*

When first seen, 1899, January 8, this star was 10.5 magnitude. It faded steadily and passed below the reach of the 6½-inch the last of March, and could not be seen when looked for in April and May. It had risen to 8¼ magnitude in November, and passed a maximum about eighth magnitude early in December, 1899, and had fallen to the eleventh magnitude in April, 1900. There is a fourteenth magnitude star 20″ south following, which will aid in identifying it in its faint stage.

2376. *S LYNCIS.*

This star passed a maximum a little brighter than the ninth magnitude in May, 1900.

2749. *S GEMINORUM.*

The observations of 1900 began too late to fix the minimum, but the star was found between the twelfth and thirteenth

magnitude in January and February and had risen to tenth magnitude April 17.

2404. *X GEMINORUM.*

A maximum at the eighth magnitude was passed in December, 1899, and a minimum at the twelfth magnitude in April, 1900. It was little, if any, past a minimum early in February, 1901.

4471. *T CANUM VENATICORUM.*

This star passed a maximum, rather brighter than the ninth magnitude in September, 1899, and a twelfth magnitude minimum in February, 1900.

4315. *R COMAE.*

After passing a ninth magnitude maximum about 1900, July 25, and fading half a magnitude, the star again brightened, and when last seen, August 18, it was as bright as at any time in July. The strong twilight rendered these estimates of small weight.

5070. *Z VIRGINIS.*

This star was again brightening during the spring of 1901, being thirteenth magnitude May 18, and twelfth magnitude June 3.

5798. *RU HERCULIS.*

The minimum of 1900 was followed with the 12- and 40-inch telescopes. The star was fainter than the thirteenth magnitude from the last of February to the first of May, the minimum, a little brighter than the fourteenth magnitude, being passed about the first of April.

5830. *R SCORPII.*

A maximum about 10.5 magnitude, was passed in August, 1900. The star was fainter than the thirteenth magnitude 1901, June 7, and fainter than the fifteenth magnitude July 8.

5831. *S SCORPII.*

This star passed a tenth magnitude maximum in May, 1900, and was found at the thirteenth magnitude and fading in June, 1901.

5601. *S URSAE MINORIS.*

This star passed an eighth magnitude maximum the latter part of June, 1900, and was again near minimum in November and December of the same year.

6100. *RV HERCULIS.*

A faint maximum, about tenth magnitude, was passed in June, 1900, and a sixteenth magnitude minimum in September of that year. It was 13.5 magnitude 1901, May 18, and 11.5 June 3.

6449. *T DRACONIS.*

After the maximum of 1899, August 15, this star faded slowly and remained fainter than its 10.5 magnitude companion from the first of December, 1899, to the last of June, 1900. It then rose to 8.5 magnitude by the middle of September, and remained at that brightness, with some fluctuations, the rest of the year.

(6452)—*HERCULIS.*

The discovery by Anderson is noted in *A. N.*, **150,** 325. The position, based on micrometer comparisons with the neighboring *Berlin A. G. Catalogue* stars, is

R. A. $17^h\ 53^m\ 27^s.7$, Decl. $+19°\ 29'\ 41''$ (1855)
$55\ 24.7$ $29\ 20$ (1900)

It passed eighth magnitude maxima about the first of March and the last of October, 1900, and a minimum between 13.5 and fourteenth magnitude, the latter part of June of the same year.

(6458)—*DRACONIS.*

The notice of discovery by Anderson is given in *A. N.*, **151,** 307. The position from micrometer comparisons with the neighboring *Cambridge A. G. Catalogue* stars, was found to be

R. A. $17^h\ 55^m\ 24.4^s$, Decl. $+54°\ 53'\ 01''$ (1855)
$56\ 17.2$ $52\ 45$ (1900)

After the rise noted in this JOURNAL, **12,** 54, the star passed a maximum about 9½ magnitude in July, 1900, and had fallen below the limit of the 6½-inch the last of October of that year.

6549. *W LYRAE.*

Maxima were found, about 8.0 magnitude in December, 1899, and June, 1900; with a twelfth magnitude minimum in March, 1900. It had risen nearly to maximum by the last of December, 1900.

6871. *V LYRAE.*

The first minimum completely observed was that of 1900. The star was 12.0 magnitude January 1, and fell steadily to a minimum about 15.5 magnitude the latter part of June, and rose to a 9.5 magnitude maximum about November 1. By the last of December it had again fallen to 11.5 magnitude. It was below the thirteenth magnitude for nearly six months, from the last of March till September. By the aid of the light curve thus obtained the minimum of the year 1899 can be located near the first of June, since the variable was below the limit of the 6½-inch from the last of February till August 9. The maximum of this year was passed in October at nearly the same brightness as that of 1900. The resulting period of a little less than thirteen months is confirmed by one observation, 1901, July 9, when the variable was found near minimum.

6894. *S LYRAE.*

The minimum reported in this JOURNAL, **12**, 53, was followed by a 9.5 magnitude maximum in September, 1900. The variable is preceded by two fifteenth to sixteenth magnitude stars, the three forming a line about ½′ long.

6899. *U DRACONIS.*

This variable passed a 13.5 magnitude minimum early in March, 1900, at a ninth magnitude maximum late in July of the same year.

7085. *RT CYGNI.*

A twelfth magnitude minimum was passed in December, 1899, a 7.5 magnitude maximum in March, 1900, an eleventh magnitude minimum in June and a seventh magnitude maximum in September, 1900.

7220. *S CYGNI.*

The minima of this star prove to be extremely faint. It was at the limit of the 40-inch in July, 1900, had brightened perceptibly in August, and then rose steadily to 12.5 magnitude by the middle of November. The observations began too late to fix the date of minimum, but it was probably late in July.

(7248)—*AQUILAE.*

Anderson's discovery of this variable is reported in *A. N.*, **147,** 269. Its position from micrometer comparisons with $+12^{\circ}$ 4255 (*Bonn* VI) is

R. A. $20^{h}\ 5^{m}\ 56^{s}.3$, Decl. $+12^{\circ}\ 33'\ 46''$ (1855)
$8\ \ 3.1$ $41\ 41$ (1900)

Near its minimum in 1899 it was invisible in the 6½-inch from August 9 to November 22. It passed a maximum too near the Sun for observation, during the interval between 1900, January 2 and March 2; then faded from eleventh magnitude in March to a 14½ magnitude minimum early in June; then rose to an 8½ magnitude maximum in October, and had fallen to the twelfth magnitude at the last comparison, 1900, December 19.

There is a 12½ magnitude star 32″ north of the variable.

(7258)—*CYGNI.*

The discovery by Anderson is noted in *A. N.*, **150,** 325. The position from micrometer comparisons is:

R. A. $20^{h}\ 9^{m}\ 44^{s}.7$, Decl. $+30^{\circ}\ 37'\ 56''$ (1855)
$11\ \ 32.9$, $46\ \ 3$ (1900)

After the minimum reported in this JOURNAL, **12,** 54, the star rose steadily to a maximum about 9¼ magnitude in October, 1900, and had fallen to the twelfth magnitude by the last of December.

7379. *ST CYGNI.*

After the maximum of 1899, May 30, the star fell steadily and passed below the limit of the 6½-inch the last of September of that year. It was next glimpsed with the 6½-inch 1899, December 5, and rose to a 9½ magnitude maximum about 1900, May 1. The following minimum, observed with the 12- and the 40-inch telescopes, was not sharply defined, the star remaining near 13.5 magnitude during August, September, and October of 1900, and rising to 10½ magnitude by the last of December. As the positions of six of the neighboring stars were measured with the 40-inch and the field made quite familiar, it does not seem that misidentification was to be feared.

7458. *V DELPHINI.*

In continuation of the report in this JOURNAL, **12**, 54, this star remained at or below the limit of the 40-inch during the interval July–October, 1900. There is a sixteenth magnitude star 1′ south and a trifle following the variable.

7492. *RZ CYGNI.*

This star passed a twelfth magnitude minimum in January, 1900, and fluctuated between that brightness and 10.5 magnitude for the remainder of the year.

7502. *X DELPHINI.*

This star remains for several weeks at minimum below the limit of the 6½-inch. It passed a maximum, a little brighter than the ninth magnitude, in the latter part of June, 1899, and had faded to the limit of the 6½-inch at the last comparison of the season, November 27. It was again near maximum 1900, May 1, and faded gradually till the last of October, when it was between 13½ and fourteenth magnitude.

(7579)—*CEPHEI.*

The discovery by Madame Ceraski is reported in *A. N.*, **147**, 142. The position from micrometer measures is

R. A. $21^h\ 6^m\ 39^s.2$, Decl. $+82°\ 28'\ 58''$ (1855)
$3\ 38.5$ $39\ 50$ (1900)

The variable remained below the limit of the 40-inch from 1900, May 29, to October 16. On October 25 it was about sixteenth magnitude, and 1901, January 24, it had risen to fourteenth magnitude, while May 16 it was near maximum, about 10½ magnitude. By the kindness of the then Director Keeler a photograph of the field was taken, with two hours' exposure, with the Crossley telescope of the Lick Observatory, 1900, July 24, which showed the variable about half a magnitude fainter (photographically) than the visual limit of the 40-inch.

(7594)—*AQUARII.*

This is *S. DM.* $-4°$ 5381. Its discovery by Barnard is given in this JOURNAL, **19**, 193. Its place for 1855 is

R. A. $21^h\ 3^m\ 22^s.7$, Decl. $-4°\ 37'.4$

It passed below the limit of the 6½-inch the latter part of October, 1899, and was again past maximum and fading from tenth to eleventh magnitude in April and May, 1900. It was near minimum, rather fainter than fourteenth magnitude, 1900, June 28, and rising steadily passed a tenth magnitude maximum in October of that year.

(7656)—*PEGASI.*

The discovery of this variable by Anderson is recorded in *A. N.*, **147,** 287. Its position from micrometer comparisons with neighboring catalogue stars is

$21^h\ 14^m\ 7^s.5$, Decl. $+13°\ 50'\ 17''$ (1855)
$16\ \ 14.9\ \ \ \ \ \ \ \ 14\ \ 1\ \ 36$ (1900)

Minima were observed, about thirteenth magnitude, late in December, 1899, and in July, 1900. Maxima at 8½ magnitude were passed early in March and in October, 1900.

7896. *V PEGASI.*

After the maximum of July, 1899, the variable faded slowly and passed below the limit of the 6½-inch the last of November. It was next seen 1900, May 1, at 9.0 magnitude and passed an eighth magnitude maximum the latter part of May, then faded slowly to fourteenth magnitude when last observed, 1900, October 24.

8324. *V CASSIOPEIAE.*

Minima at about 12.5 magnitude were passed in December, 1899, and early in August, 1900. Maxima at 7½ magnitude were found in March and early in November, 1900.

(8517)—*CASSIOPEIAE.*

R. A. $23^h\ 39^m\ 39^s.9$, Decl. $+56°\ 1'\ 34''$ (1900)

The discovery by Anderson and measures of position by Hartwig are given in *A. N.*, **148,** 79, and **149,** 6, respectively. The variable was 10½ magnitude and fading early in January, 1899. It passed below the limit of the 6½-inch early in April and remained invisible in that instrument the rest of the year. It was found between the fourteenth and fifteenth magnitude

with the 40-inch in January, 1900, rose to a 9½ magnitude maximum in March, and fell to 12.5 magnitude the last of August, 1900.

(8629)—*CASSIOPEIAE.*

The discovery by Mrs. Fleming, and the position for 1900,

R. A. $23^h\ 55^m\ 53^s$, Decl. $+54°\ 52.3$,

are given in *Harvard College Observatory Circular* No. 24.

After the maximum of 1899, April 8, the variable faded slowly, passing below the limit of the 6½-inch in September and remaining invisible in that instrument for the rest of the year. A minimum at about 13.5 magnitude was observed with the 12- and 40-inch telescopes in January, 1900, followed by a 9½ magnitude maximum in June. It had passed below the twelfth magnitude in November, 1900.

YERKES OBSERVATORY,
September 6, 1901.

THE WAVE-NUMBER SYSTEM OF RHODIUM.

By C. P. SNYDER.

PURSUANT to the advice of the late Professor Rowland the writer presents the results of his investigations on the wave-number relations in the arc-spectrum of rhodium; which results are embodied in the "Rhodium Table," and description following. The table contains 476 wave-numbers out of a total of 1471; that is, it contains about 32 per cent. of the total number.

DESCRIPTION OF THE RHODIUM TABLE.

In the columns headed A, B, C–S, and rows numbered 1, 2, 3–52, are given certain wave-numbers of the arc-spectrum of rhodium as given by Kayser. Between the columns A, B; B, C; etc., are given the differences between successive wave numbers in the same line; and, between the rows 1, 2; 2, 3; etc., are given the differences between successive wave-numbers in the same column. It will be noticed that for any pair of columns all the differences obtained by subtracting corresponding wave-numbers are the same; and, of course, the same is true for any pair of rows. By corresponding wave-numbers in the columns I mean those found upon the same line in the table.

It will also be noticed that there are what may be called complementary columns, as I and M, G and H, etc., in which the gaps of one correspond to the wave-numbers found in the other. For example, in H there is a wave-number on line 3, but none on 4 or 5; in S there are wave-numbers on lines 4 and 5, but none on 3, etc. There are also groups of rows in which a series of gaps is repeated, *e. g.*, for each of the rows 5, 7, 11, 15, 22, 36, 43 we find gaps in the columns H, I, J, N, O.

It may also be readily seen that the wave-numbers of "reversed" spectral lines (indicated by *r*) are to be found only in the "final" columns of the table. This relation seems to be connected with that which determines the distinction between

"rows" and "columns" in the table, viz., the number of rows should considerably exceed the number of columns.

[In addition to the foregoing relations, the writer thinks he has found, in the arc-spectrum of palladium (as given by Kayser), a "sub-system" which has the same series of wave-number differences as that of the "principal system" for the given element; except that the order of differences is reversed; thus, where the principal system has the column of wave-numbers A, $A+d_1$, $A+d_2$, etc., the sub-system has a column of wave-numbers B, $B-d_1$, $B-d_2$, etc; this relation may be connected with the occurrence, in the given spectrum, of two sets of lines, shaded in opposite directions.]

In addition to the rhodium table the writer has found a quite extensive system for ruthenium, containing several hundred wave-numbers; also systems for iridium, nickel, platinum, palladium, and osmium.

NOTE.—Rows 23½ and 44½ were omitted by error, and are not included in the computations of mean differences of wave-number between successive rows and columns.

As subsequent investigation will probably alter the positions assigned to some of the wave-numbers, the writer has spent little time in estimating the most probable values of the aforementioned mean differences. A much more accurate estimate of these mean differences might be obtained by including Professor Rowland's values for the arc-spectrum of the element.

	A	B	C	D	E	F	G
1							
2							
3							
4							4 1670717 (493163) 43574
5							4 1714291 (350168) (123517)
6							
7						4 1758059 79749 (37270)	4 1837808 (350167) (51221)
8					2 1717159 (200648) (452246)		
9						0 1795329 (320724) (52948)	
10			1 1682550 (206479) 39074				4 1889029 75476 39020
11			4 1721574 (126703) 4230			2 1848277 79772 (23925)	1 1928049 (350151) (103989)
12			4 1726804 40565 19694	4 1766369 (516057) (182073)			
13			3 1745408 (126704) (309048)			0 1872202 (320708) (80075)	
14							
15	1 1692109 (259968) (90200)					1 1952277 79761 82313	2 2032038 (350145) (308855)
16		2 1774784 (173658) 7930		2 1948442 (86148) 7926		2 2034590 (155210) (153693)	
17	4 1782509 205 138761	3 1782714 (173654) (303889)		2 1956368 (406849) 138753			
18	2 1921270 (133276) (165126)		4 2054546 40575 (145337)	2 2095121 (241369) 7035			
19				4 2102156 (86127) 26522		2 2188283 (251441) (72831)	
20				1 2128678 40727 (299900)	2 2169405 (200653) (254130)		
21						0 2261114 79779 65489	2 2340893 (350155) 65474
22			4 2199883 (126720) 19778			4 2326603 79764 (122522)	2 2406367 (350146) (122519)
23	0 2086396 207 (173270)	3 2086603 133058 (105267)	4 2219661 (281953) (173294)				
24						2 2440125 79761 2537	2 2528886 (350158) (227184)
25		5 2191870 (259792) (63066)				4 2451662 (155248) 17286	
26					2 2423535 45413 (59577)	3 2468948 (155232) 45780	
27		4 2254936 (173642) 4924		4 2428578 (86150) (56255)		5 2514728 (155236) (45799)	
28	3 2259666 194 (40863)	1 2259860 133095 (40871)	1 2392955 (281922) (126305)				
29					1 2483112 (200638) (179659)		
30	3 2300539 202 (145008)	2 2300731 (259796) 10458				2 2560527 (155217) (66123)	
31		0 2311189 (173644) (105349)		5 2484833 (241378) 29409			
32				2 2514242 (241360) 26269			
33				2 2540511 (86139) 19320		4 2626650 (155231) 19322	
34			2 2519260 40571 (62311)	1 2559831 (86141) (59566)		4 2645972 (320707) (30350)	
35							
36		0 2416538 (259784) (313627)				4 2676322 79748 29207	4 2756070 (350190) (221073)
37	4 [illegible] (173860)			1 2619307 (86132) (2757)		2 2705529 (155239) 2656	
38					3 2662771 45414 122	2 2708185 (155222) (29640)	
39			2 2581571 40583 [illegible]	2 2622154 40739 29537	4 2662893 (200636) (182671)		
40				4 2641691 (86134) 153132		2 2737825 (155220) 153150	
41				2 2804823 40741 (98991)	4 2845564 45417 (384858)	6 2800975 (155248) 6396	
42			4 2770656 (126715) (128160)			5 2897371 79772 55206	2 2977143 (350176) 55203
43						6 2952577 79769 37393	4 3032346 (350161) (154052)
44	3 2729966 199 35563	2 2730165 (173649) 35563		4 2903814 (86156) 35577		2 2989970 (155260) 35575	
45	4 2765529 199 81101	1 2765728 133088 81102	5 2898816 40575 81102	3 2939391 (86154) (100967)		2 3025545 (320703) 81087	
46	4 2846630 200 (19830)	3 2846830 133088 (19860)	4 2979918 (126714) (19854)			4 3106632 79766 3268	4 3186398 (350154)
47						0 3109900 (155242) (165943)	
48	3 2866480 210 (316774)	3 2866690 133082 149356	1 2999772 40586 (316745)	2 3040358 (241374) (196616)			
49		2 3016046 (214376) (167404)			2 3230422 45421 47279	2 3275843 (155217) (167374)	
50				2 3236974 40727	0 3277701 (200631)		
51	1 3183254 196 84353	0 3183450 133067	2 3316517 (126700) 84346			2 3443217 (155245) 84373	
52	2 3267607 (133256)		2 3400863 (126727)			1 3527590 (320732)	
23½				2 2298569 40746	4 2339315 (200642)		
44½				5 2934576 40739	6 2975315 (200671)		
Mean differences	202	133079	40575	40733	45414	79764	75476

WAVE-NUMBER SYSTEM OF RHODIUM.

	I		J		K		L		M		N	
				1	6N 1785350 (178443) 143008		4 1928358 (178423) 210007		7 2138365 (238100) 146733			
			4N 1822850 (462248) 31718	2					7N 2285098 (416079) 31692			
(165466)			5 1854568 (153774) 109225	3	5 1963793 (100666) 142988		6 2106781 57099 210009		2 2316790 57116 3304		2 232009 (22869	
				4			5 2163880 43553 210026		5N 2373906 (569079) 43544			
				5	4 2064459 53089 142974		5 2207433 (123533) 210017		4N 2417450 (309274) (123539)			
96228	5 1939074 (74948) 69268		4 2008342 (74929) 109206	6	6 2117548 (574829) 70427							
				7	6 2187975 (37274) 142991		7 2330966 (90212) 210023		4N 2540989 (238097) (37296)			
96215	4 2014022 (271997) 69249		4 2083271 (465521) 32782	8							4 254879 3277	
			2 2116053 (76857) 109196	9	4 2225249 (353036) (52951)				2 2578285 13010 3286		0 258157 (5716	
(627690)				10					4N 2592105 (416076) 39122			
				11	1 2278200 4226 142978		6 2421178 4235 210039		4N 2631217 (238090) 4231			
				12	5N 2282426 19704 142987		4 2425413 10708 210035		4N 2635448 19692 3292		5 263874 1970	
			4 2192910 3406 109220	13	1 2302130 3412 142991		4 2445121 3417 210019		5N 2655140 (80042) 3303		2 265·44 340	
(165439)			6 2196316 (158970) 109226	14	1 2305542 76641 142996		5 2448538 76648 (213306)				2 266184 (15894	
				15	3 2382183 82319 143003		5N 2525186 82320 209996		5 2735182 (238117) (90268)			
96219	5 2286019 (153705) 69267		4 2355286 7931 109216	16	3 2464502 (146677) 143004		5N 2607506 7926 (213278)				5 282078 (14609	
			2 2363217 (252215) 138738	17			4N 2615432 (145754) 210018		3 2825450 (238087) 138724			
(165465)			4 2501955 7040 109224	18	2 2611179 7029 (352995)				2 2964174 (79894) 3307		3 296748 702	
	5 2439724 26535 69271		5 2508995 26531 109213	19	5 2618208 (72840) 142978		5 27611186 (213324) (138319)				8 297451 2654	
96201	3 2466259 (236848) 69267		5 2535526 (465529) (131548)	20							4 300105 (13156	
				21	4 2691048 (353030) 65465				0 3044068 (238113) 65488			
				22	7 2756513 19786 142992		6 2899505 19781 210051		4 3109556 (238079) 19770			
(165460)			5 2667074 (105285) 109225	23	4 2776299 102745 142987		4 2919286 102775 210040		4 3129326 (168351) 3293		6 313261 (10529	
				24	5 2879044 2528 143017		3 3022061 2532 (519275)					
96197	3 2703107 17278 69252		5 2772359 (63079) 109213	25	0 2881572 (63096) 143021		4 3024593 17281 (213316)				4 323790 1729	
96205	5 2720385 45784 (321489)			26			4 3041874 45788 (213326)				3 325520 4577	
96205	1 2766169 (13780) 69269		2 2835438 4925 109230	27	3 2944668 4930 142994		4 3087662 4923 210015		0 3297677 4924 3298		4 330097 494	
(65486)			2 2840363 8853 109235	28	3 2949598 (40853) 142987		4 3092585 (40866) 210016		2 3302601 (40872) 3314		3 330591 883	
96199	4 2779949 (42471) 69267		1 2849216 (465532) 32008	29							0 331474 3200	
(65480)			5 2881224 10463 109227	30	5 2990451 10451 143006		3 3133451 10477 210022		2 3343473 (66116) 3281		5 334075 10.6	
96209	4 2822420 29393 69267		5 2891687 29394 109215	31	4 3000902 29404 143026		5 3143928 29387 (213286)				5 335721 2940	
96211	4 2851813 (60923) 69268		3 2921081 26260 109225	32	2 3030306 26278 143009		4 3173315 26281 (213299)				1 338661 (4558	
(65460)			2 2947341 10338 109243	33	3 3056584 19327 143012		2 3199596 19317 209993		4 3409589 (221838) 19331			
			5 2966679 15322 109232	34	2 3075911 (30349) 143002		1 3218913 (30361) 210007		4 3428920 (30340) 3283		4 343220 1532	
	2 2912736 (46895) 69265		2 2982001 (465524) (44262)	35							2 344752 (4424	
				36	4 3106260 29213 143014		2 3249274 29197 209986		4 3459260 (238137) 29219			
(5495)			0 3026263 2631 109210	37	1 3135473 2664 142998		2 3278471 2649 210008		2 3488479 (247076) 3287		6 349176 265	
6224	4 2959631 94 69263		4 3028894 115 109243	38	5 3138137 (182767) 142983		4 3281120 (182754) (213296)				4 34944 13	
6196	2 2959725 29562 69284		2 3029009 (465544) 29545	39							3 349455 2953	
6242	5 2989287 153162 69267		5 3058554 (465531) (252129)	40							4 352408 15314	
6226	3 3142149 (218889) (178455)			41	0 3320904 6415 142970		4 3463874 6417 (213358)				2 367723 (9899	
				42	5 3327319 55188 142972		1 3470291 55195 (448144)					
				43	2 3382507 37376 142979		1 3525486 37395 210069		4 3735555 (238100) 37376			
(5453)			2 3310683 35565 109200	44	4 3419883 35575 142998		2 3562881 35581 210050		1 3772931 35555 3294		4 377622 3558	
			3 3340248 (84342) 109210	45	1 3455458 81094 143004		4 3598462 81119 210024		0 3808486 81111 3322		4 381180 (8433	
				46	4 3536552 (19876) 143029		2 3679581 3271 210016		2 3889597 (420986)			
6196	3 3361338 (165938) 69252		4 3430590 (252262) 16602	47			4 3682852 16573 (213290)				2 389614 1658	
(5460)			4 3447192 149338 109236	48	3 3556428 (310753) 142997		2 3699425 149328 (213304)				0 391272 (19661	
6216	4 3527276 47280 69254		3 3506530 (252223) 47303	49			0 3848753					
6224	3 3574556 69277		0 3643833 (465511) 120130	50							1 410934	
(5501)			2 3763963 84359 109218	51	2 3873181 84337							
			2 3848322 109196	52	1 3957518 (353065)				2 4310583			
(2004)				23½							6 317096	
(5439)			2 3341425 109228	44½	0 3450653 (356346)						3 380699	
6212		69265				142996		210021		3297		

N	O	P	Q	R	S	Mean Differences	
		2 2376465 71173 (178429)	2 2447638 106808 (178427)	4 2554446 152987 146731	10r 2707433 146718	146727	1
2 2320094 (234800) (228698)		2 2554894 71171 (153738)	4 2626065 106796 (100659)	8r 2701177 152974 31684	8r 2854151 (88834)	31698	2
				8r 2732861 (100666)	8r 2942985 43534	57107	3
			7 2726724 106803 53101	7r 2833527 152992 (123543)	1 2986519 (123563)	43551	4
	4r 2692377 16255 (74923)	4r 2708632 71193 70454	4r 2779825 70433			53095	5
		6r 2779086 71172 (37280)	4r 2850258 106812 (37276)	4 2957070 153019 (37290)	4 3110082 (51189)	70438	6
4 2548792 218508 32779	5r 2767300 (89951)						7
0 2581571 (234795) (57169)		5 2816366 71168 (52941)	5r 2887534 106826 (52969)	7 2994360 13011		32780	8
				6r 3008271 153000 39018	1 3161271 39031	13910	9
		4 2869307 71196 4224	7 2940503 106786 (23928)	4r 3047289 153013 4240	6 3200302 (103976)	39023	10
5 2638740 218511 19703	7 2857251 16280 19691	4r 2873531 (177998) 14704		4 3051529 19702		4231	11
2 2654443 218499 3401	5r 2876942 16293 3416	4 2893735 71196 3416	7 2964431 106800 3398	4 3071231 (80079)		19699	12
2 2661844 218514 (158940)	4r 2880358 16293 (158970)	4 2896651 71178 76648	6 2967829 76652			3409	13
		5 2973499 71182 82308	4r 3044481 106822 82315	4 3151303 152975 (90235)	2 3304278 (228996)	76647	14
5 2820784 218544 (146097)	5 3030328 16279 (146689)	8 3055607 71189 7930	4 3126796 7936			82315	15
		8 3063537 71195 138753	5 3134732 106806 138743	4 3241538 (218608)		7929	16
3 2967481 218536 7029	5 3186017 16273 7029	6 3202290 71185 7043	2 3273475 (259799) 7033		2 3533274 (145367)	138745	17
8 2974510 218536 26545	4 3193046 16287 26537	5 3209333 71175 26538	0 3280508 (72845)			7034	18
4 3001055 218528 (131564)	4 3219583 16288 (131571)	0 3235871 46310				26534	19
		3 3282181 71172 65454	2 3353353 106793 65476	4 3460146 (85256)		46310	20
		7 3347635 71194 10777	4 3418829 (259812) 19761		3 3678641 (122526)	63474	21
6 3132619 218535 (105290)	4 3351154 16258 (105286)	6 3367412 71178 (105296)	3 3438500 106812 102746	3 3545402 102771		19775	22
			2 3541336 106837 2552	2 3648173 152994 (111405)	9 3801167 (227160)	102759	23
4 3237909 218531 17291	4 3456440 16268 (76834)	4 3472708 71180 (63050)	3 3543888 17264			2537	24
3 3255200 (305952) 45775			2 3561152 45810			17278	25
4 3300975 (234783) 4940		4 3535758 71204 4920	4 3606962 4929			45786	26
3 3305915 (234763) 8833		2 3540078 71213 (40885)	4 3611891 (40872)			4925	27
0 3314748 218526 32006	2 3533274 32006					8853	28
5 3346754 218526 10460	2 3565280 16283 10450	4 3581563 71200 10463	3 3652763 106815 10475	2 3759578 (66109)		32003	29
5 3357214 218516 29400	2 3575740 16296 (55697)	5 3592026 71212 29404	6 3663238 29379			10462	30
1 3386614 (234816) (45589)		2 3621430 71187 26886	2 3692617 26300			29395	31
	2 3631427 16289 10337	2 3647716 71201 (34618)	2 3718917 106770 10309	0 3825687 (49671)		26279	32
4 3432203 218561 15322	2 3650764 (87462) 15295		3 3738226 15295			19325	33
2 3447525 218534 (44241)	0 3666059 16275 (44256)	0 3682134 71187 15063	0 3753521 15053			15308	34
		6 3697397 71177 29213	5 3768574 106784 (31862)	0 3875358 152969 29254	0 4028327 (61547)	15058	35
6 3491766 218549 2650	4 3710315 16295 2676	2 3726610 (178002) 1650		2 3924612 (191815)		29217	36
4 3494416 218575 137	2 3712991 16269 101	4 3731260 71176 (29646)	2 3800436 (29632)			2651	37
3 3494553 218539 29532	2 3713092 29532					115	38
4 3524085 218539 153147	4 3742624 16282 153140	2 3758906 71162 153151	0 3830068 (259806) 153156		4m 4089874	29537	39
2 3677232 218532 (98993)	2 3895764 16293 (98986)	4 3912057 71167 6378	2 3983224 6406			153152	40
		2 3918435 71195 55220	2 3989630 106797 55198	2 4096427 55204		6402	41
		2 3973655 71173 37364	2 4044828 106803 37388	2 4151631 37373		55202	42
4 3776225 218525 35583	2 3994750 16269 (119913)	2 4011019 71197 35560	2 4082216 106788 35553	0 4189004		37380	43
4 3811808 (234780) (84334)		2 4046588 71181 (100954)	2 4117769 (100993)			35569	44
						81102	45
2 3896142 218521 16587	2 4114663					3269	46
0 3912729 (234813) (196615)						16588	47
		0 4147542 71220	2 4218762			149337	48
1 4109344						47283	49
						120130	50
						84353	51
							52
6 3170961 218503	1 3389464						23½
3 3806999 218511	2m 4025510						44½
218531	16280	71186	106803	152990			

SPECTROSCOPIC STUDIES.[1] I.

By EDUARD HASCHEK.

I. COMPUTATION OF THE PRESSURE IN THE SPARK FROM THE DISPLACEMENTS OF THE LINES.

THE effect of pressure upon the wave-length of lines in the electric arc has been investigated for a large number of elements by W. J. Humphreys and J. F. Mohler[2] in a series of researches undertaken, in part individually, and in part in collaboration. The principal results of their work are the following: With increase of pressure in the gas surrounding the arc the individual lines in the arc spectrum become displaced toward the red, with the increase of wave-length proportional to the pressure of the gas. The displacement of the lines varies with the element, and is a periodic function of its atomic weight. Within a single spectrum, however, the displacements also vary, and are proportional to the wave-length of the line, so that for a definite number of lines referred to the same wave-length they are constant. If one compares the lines of different series of the same element, then the relative displacements are found to be in the ratio 1:2:4.

In view of the above-mentioned results of Humphreys and Mohler, it is natural to infer the existence of pressure in all cases of incandescent gases in whose spectra displacements of the lines are observed, and so long as we know of no other causes which might occasion a variation in wave-length it is permissible to compute the amount of the pressure from these displacements. Both of these conclusions have been drawn. Thus F. Exner and E. Haschek,[3] in the course of their measures of the ultra-violet spectra of the elements, observed considerable

[1] *Sitzungsberichte der Kais. Akad. der Wiss. in Wien.* Math.-naturwiss. Classe. 110, Abth. II, March, 1901.

[2] ASTROPHYSICAL JOURNAL, 1896, 1897.

[3] *Sitzungsberichte der Kais. Akad. der Wiss. in Wien*, 1897 ff.

displacements of the spark lines analogous to those in the arc, and explained them on the ground of pressure in the spark, deriving the amount of this pressure from the absolute magnitude of the displacements. The pressure in the path of the electric discharge was then observed directly by E. Haschek and H. Mache,[1] and its dependence upon the experimental conditions quantitatively determined. The values thus obtained are considerably larger than those computed from the displacements, and the difference is not capable of explanation on the simple ground of inaccuracies of observation. Finally J. F. Mohler,[2] also from the displacements of the lines, determined the pressure in the spark of an induction coil, and found small values corresponding to the slight displacements. It is noteworthy, however, that the ratio between the pressure found directly and the computed pressure is nearly the same in the case of the induction coil as in that of the transformer which E. Haschek and H. Mache employed chiefly, and lies between 2 and 2.5.

These discrepancies between the values of measurement and those of the indirect determination of the pressure in the spark cause one to doubt the admissibility of directly applying to the spark the results of Humphreys and Mohler. It will be shown in the following paper that other laws govern the displacements of spark lines from those of the arc, and hence that a derivation of the spark pressure from the displacement of the lines is not admissible. For this we need to know the displacements of a larger number of spark lines, for which the corresponding quantities in the arc spectrum are also given in Humphreys' comprehensive research. It is clearly not allowable to compute the pressure in the spark from the displacement of lines which have not been investigated in the arc. In the case of most elements the relation of the lines to the series is not known, and so the possibility is excluded of applying the last of the above-mentioned results of Humphreys.

[1] *Sitzungsberichte*, etc., 1898.

[2] ASTROPHYSICAL JOURNAL, 10, 202, October, 1899.

If it is allowable to infer a pressure in the spark from displacement of the lines, it is clear that the displacement for all the lines must furnish the same value for the pressure, if no other influences are at work. If such influences are present, however, the values will, in general, prove different, and cases may be imagined in which certain external conditions will influence many lines or groups of lines differently from others. Consequently it will not necessarily follow that the empirical classification of lines in series will hold good in all cases.

Our first problem, then, will be to determine the displacements for a considerable number of lines of different elements, all of which have been obtained under nearly identical external conditions, and from these displacements to compute the pressure in the spark. After this we shall have to seek for other causes which have to do with the displacements of lines, and to attempt to determine the laws which govern the variations in wave-length.

The material for the first part of our investigation is furnished us by the measures of Professors F. Exner and E. Haschek upon the ultra-violet spark spectra of the elements, all of which have been carried out under the same conditions and with the same degree of accuracy. The values which are employed here are taken in part from publications and in part from a new determination of the spectra, which is soon to be issued. In order to avoid a great number of tables, we shall note here only those lines which show a plain displacement, taking as a lower limit for this the value of 0.03 t. m. The measures of the spark spectra are on the average accurate to 0.015 t. m., and consequently deviations up to 0.02 t. m. will be regarded as errors of observation. Larger errors will occur but very seldom.

To determine the displacements of the spark lines we apply for comparison the values in the arc spectrum. Where possible, only the results of Rowland, in part for the arc and in part for the solar spectrum, have been employed, but since the values of the lines in the two cases do not completely agree, the figures have been rounded off to two decimal places.

The first three columns of the following tables need no explanation. In the fourth column $\Delta(\lambda \text{ spark} - \lambda \text{ arc})$ denotes the displacement of the spark line, and in the fifth, $\Delta\lambda$ the displacement of the arc line[1] for a pressure of one atmosphere in the surrounding gas. The ratio $\frac{\Delta\,(\lambda \text{ spark} - \lambda \text{ arc})}{\Delta\lambda}$ gives the pressure in the spark, which is given in atmospheres in the sixth column and denoted by P.

Element	λ (Arc)	λ (Spark)	Δ (Spark − Arc)	Δ λ	P
Al	3092.82	3092.89	0.07	0.0049	14
	3944.16	3944.22	0.06	0.0043	14
	3961.68	3961.74	0.06	0.0047	13
Ge	3269.63	3269.70	0.07	0.0026	27
	4226.72	4226.76	0.04	0.0043	9
n	3302.72	3302.75	0.03	0.0031	9
	3345.16	3345.20	0.04	0.0029	14
	3382.46	3282.49	0.03	0.0030	10
	4680.32	4680.43	0.11	0.0064	17
	4722.34	4722.50	0.16	0.0057	28
Ca	3159.00	3159.11	0.11	0.0052	21
	3179.45	3179.60	0.15	0.0646	33
Si	2516.21	2516.26	0.05	0.0014	35
	2881.70	2881.73	0.03	0.0025	12
	3905.66	3905.71	0.05	0.0035	14
Zr	3958.36	3958.39	0.03	0.0014	21
	3999.12	3999.18	0.06	0.0027	22
	4029.80	4029.88	0.08	0.0026	31
Cr	3886.93	3886.97	0.04	0.0022	18
	3919.31	3919.36	0.05	0.0018	28
	3963.83	3963.88	0.05	0.0026	19
	3984.06	3984.09	0.03	0.0032	9
	4280.56	4280.59	0.03	0.0024	13
i	3200.03	3200.07	0.04	0.0026	15
	3234.64	3234.72	0.08	0.0017	47
	3242.13	3242.19	0.06	0.0014	43
	3254.31	3254.41	0.10	0.0020	50
	3326.91	3326 99	0.08	0.0016	50
	3341.97	3342.00	0.03	0.0018	17
	3349.04	3349.14	0.10	0.0014	71
	3361.33	3361.40	0.07	0.0011	64
	3380.40	3380.45	0.05	0.0019	26
	3900.68	3900.81	0.13	0.0020	65
	3904.93	3904.98	0.05	0.0018	28
	3913.61	3913.72	0.11	0.0018	61
	3924.67	3924.72	0 05	0.0015	33
	3958.36	3958.39	0.03	0.0018	17
	3981.92	3981.96	0.04	0.0020	20
	3989.91	3989.95	0.04	0.0015	27
	3998.79	3998.86	0.07	0.0016	44

[1] Computed from all the individual observations.

Element	λ (Arc)	λ (Spark)	Δ (Spark − Arc)	Δ λ	P
	4009.08	4009.11	0.03	0.0015	20
Ce	3895.22	3895.29	0.07	0.0031	23
	3896.92	3896.98	0.06	0.0021	29
	3921.86	3921.90	0.04	0.0034	12
La	3929.36	3929.40	0.04	0.0026	15
	4043.05	4043.18	0.13	0 0036	36
	4086.86	4086.90	0.04	0.0026	15
Sc	4314.25	4314.32	0.07	0.0025	28
	4320.91	4321.01	0.10	0.0022	45
Y	4309.78	4309.81	0.03	0.0011	27
	4422.76	4422.80	0.04	0.0020	20
Cs	4555.44	4555.80	0.36	0.0201	18
	4593.34	4593.50	0.16	0.0133	12
Va[1]	3922.56	3922.63	0.07	0.0016	44
	3925.35	3925.40	0.05	0.0017	29
	3934.11	3934.19	0.08	0.0006	133
	3990.71	3990.80	0.09	0.0028	32
	3992.97	3993.00	0.03	0.0019	16
	4051.20	4051.25	0.05	0.0020	25
	4051.49	4051.60	0.11	0.0024	46
	4092.82	4092.92	0.10	0.0013	77
	4105.32	4105.40	0.08	0.0029	28
	4123.54	4123.74	0.20	0.0023	87
	4128.25	4128.30	0.05	0.0024	21
	4132.10	4132.21	0.11	0.0016	69
	4134.60	4134.72	0.12	0.0028	43

An examination of the above tables shows at once that only in extremely few cases is the computed pressure approximately constant for all the lines. Yet this really means but little. In the tables only lines with a considerable displacement have been included. All those for which Δ (λ spark–λ arc) $=0$ furnish a zero pressure. Indeed, it happens very rarely that the wave-lengths in the spark spectrum are smaller than those in the arc.[2] The displacement and hence the pressure is therefore negative. In general the computed pressures differ so widely from one another that one cannot but conclude that other causes are instrumental in determining the displacement of the lines. The

[1] The results of H. A. Rowland and C. N. Harrison for the arc spectrum (ASTROPHYSICAL JOURNAL, Vol. VII, No. 4, April, 1898) are clearly too low, as is seen from the wave-lengths of the *Ca* lines, which were allowed to remain in the spectrum and were measured with them. The difference is not a constant one, and hence is difficult of correction. The above values were taken from the solar spectrum.

[2] Compare F. EXNER and E. HASCHEK, "Über die ultravioletten Funkenspectra der Elemente," Section XI, *Sitzungsberichte*, etc., 107, 1898.

differences are not capable of explanation on the ground of inaccuracies of observation, although it must be admitted that the absolute values of the displacements of the lines in the spark spectrum do not possess the accuracy of those of the arc. Still, errors of observation can influence the results seriously only in cases of small displacements.

The values given indicate still more. According to the results of Humphreys, lines admit of arrangement according to the displacements which they suffer. Lines with an equal displacement can be classed in groups which belong together, and it then becomes evident that exactly the same lines which have been arranged in series by Kayser and Runge are indicated by their relatively equal displacements. If the results of Humphreys held true generally this relation would have to exist for the spark as well. Comparison of the observed displacements shows, however, that many of the lines for which Humphreys found large displacements alter their wave-lengths but little in the spark, and conversely. This behavior is especially marked in the case of *Ti* and *Va*. The lines $\lambda 4051.2$ and $\lambda 4051.5$ (*Va*) show nearly equal displacements in the arc, while in the spark their displacements are in the ratio 1 : 2. On the other hand the lines $\lambda 4132.1$ and $\lambda 4134.6$ (*Va*), which have nearly equal displacements in the spark, exhibit in the arc a marked difference from one another in this respect. Similar cases might be mentioned. The behavior of *Ca* is especially striking. Humphreys observed considerable displacements in a large number of the lines of this element. In the spark, however, only two appear to be displaced, all the others showing no shift, although anything of the sort would have been detected readily.

If we summarize the results so far found we have the following:

1. There occur in the spark spectrum considerable displacements of lines in the direction of an increase of wave-length, which are analogous to those observed by Humphreys and Mohler in the arc under pressure, but which attain higher values.

2. If these displacements of the lines are assumed to be dependent solely upon the pressure existent in the spark, this pressure

being experimentally determined, and if the pressure in the spark is computed from the displacement in the spark and in the arc, then values will be found for the same element which vary greatly according to the line chosen.

3. Lines with equal displacements in the arc show very different displacements in the spark, and conversely. The rule that the lines of the series of Kayser and Runge show relatively equal displacements is not confirmed for the spark.

II. CONCERNING THE DEPENDENCE OF THE WAVE-LENGTH UPON THE DENSITY OF THE LUMINOUS VAPOR.

We have hitherto always regarded the shift of the lines as dependent upon pressure in the path of the spark and have considered the spark pressure the sole cause. Previous investigations show, however, that still other causes can be found. Of course it is difficult to obtain always the same conditions for an experiment. In fact the investigation conducted by Haschek and Mache,[1] "On the Pressure in the Spark," has shown that the pressure in the spark depends to a great extent upon the arrangement of the experiment. We beg to repeat briefly here the results of this investigation.

A high potential transformer was used, the primary of which was fed with an alternating current of 100 volts. In the secondary circuit measured capacities could be introduced in parallel with the spark gap. It was found that the pressure in the spark depends upon the kind of electrodes used, the pressure and nature of the surrounding gas, and the amount of capacity employed, but not upon the length of the spark. The pressures obtained by employing the high potential transformer are quite considerable. If an induction coil be used the difference of pressure between the spark and its enveloping gas is substantially smaller, as was determined qualitatively from the measurements of Mohler.[2] In general it may be said that the pressure becomes greater as the amount of electric energy which passes between the terminals in a single spark is increased.

[1] E. Haschek and H. Mache, Astrophysical Journal, 9, 347, 1899.

[2] J. F. Mohler, Astrophysical Journal, 10, 202, 1899.

An explanation of the origin of spark pressure may be found in the investigation of H. Schuster,[1] who observes that the small particles of the metallic vapor dislodged from the electrodes move with great velocity, which diminishes sharply with increasing distance from the electrodes. From this it follows that the particles crowd together toward the middle of the path of the spark, so that the pressure increases with the distance from the electrode. A conception of how the pressure affects the wave-length of the emitted light may be obtained by considering that upon a sufficiently close approach the particles must exert mutual forces upon each other. These light producing particles will then no longer vibrate freely, but, under the influence of a dampening, which causes an increase of wave-length.

If this reasoning be correct, then, in all cases in which we increase the number of light-producing particles in unit volume, and, consequently, the density of the luminous vapor, there must result an increase of wave-length, and hence a displacement of the lines toward the red. Here those conditions which affect the pressure in the path of the discharge must of course be kept as constant as is feasible, particularly, therefore, the current strength and capacity in the secondary circuit.

Experiments on the influence of vapor density on the wave-length of the lines were made upon potassium, which shows a considerable displacement. The process was as follows: Carbon terminals were moistened with variously concentrated solutions of caustic potash in water — 100 cu. cm of the latter and 0.2, 2, 20, and 200 grams of the former. To render the carbons porous, they were warmed a few seconds in the arc. In every case the amount of solution employed was 0.75 cu. cm, so that the amounts of potassium used bore the ratio, 1 : 10 : 100 : 1000. It is permissible to assume that the numbers of the potassium particles present in the spark gap were likewise in the same ratio. The spark and arc spectra of carbons prepared in this manner were

[1] *Nature*, **57**, 1899; **59**, 1899; A. SCHUSTER and G. HEMSALECH, *Phil. Trans.*, **193**, A. 1899.

obtained photographically with a Rowland concave grating of 15 feet radius and 20,000 lines to the inch. The carbons were renewed for every experiment; the times of exposure employed were 5 and 150 seconds for arc and spark respectively. The spark was produced by a high potential transformer, supplied by a primary current of 12 amperes and 100 volts, which was transformed up to about 10,000 volts. In the secondary circuit, in parallel with the spark gap, was inserted a condenser battery of 625 meters capacity. The arc spectra were produced by a direct current of 110 volts and about 8 amperes. For all the experiments the external conditions remained the same. As measuring standards in all cases there were used the lines of the arc spectrum of iron, obtained photographically by a three-second exposure. For measurement the spectra were enlarged thirtyfold by projection and the position of the lines read off a scale. Relative to the method of measurement itself, the reader is referred to the work of F. Exner and E. Haschek.[1]

The following tables give the results of the measurements made upon the two violet potassium lines λ4044 and λ4047. It may be stated that every measurement given represents the mean of at least ten readings differing but little among themselves, and that the wave-lengths given are accurate to at least 0.002 tenth-meters for small concentration and 0.003 tenth-meters for large concentration.

A. UNREVERSED LINES.

Concentration	Arc	Spark	Arc	Spark
0.2	4044.313	4044.300	4047.374	4047.360
2.0	4044.332	4044.320	4047.387	4047.382
20.0	.....	4044.382	.....	4047.450
200.0	.....	.....	.....	4047.655

B. REVERSED LINES.

20.0	4044.310	.....	4047.365	.....
200.0 (*a*)	4044.392	4044.321	4047.392	4047.418
200.0 (*b*)	4044.392	4044.360	4047.392	.....

[1] F. EXNER and E. HASCHEK, *Sitzungsberichte*, **104**, Sec. II *a* and following.

As a consequence of an unequal moistening of the electrodes there appears in the spark spectrum at highest concentration an asymmetry between the two ends of the lines. To increase the intensity of the light there was inserted between spark and slit a quartz condensing lens which gave approximately parallel light. The ends of the lines in the spectrum always correspond to the parts of the spark which lie near the electrodes, while the middle of the line answers to the middle of the spark. If, then, the spark show non-uniformity in its direction, this, to a certain degree, will be pictured in the lines. In the case in hand, by reason of the dripping of the solution from the upper to the lower electrode, the amount of potassium entering, and therefore the amount present in the path of the spark was different at the two ends—at the upper less, at the lower greater. The result is that at the end corresponding to the less density of luminous potassium vapor only the line λ 4044 appears reversed, while at the other both appear so. In the arc as also in the spark the reversal was not accurately symmetrical; in the latter case, morever, the red component was regularly stronger than the violet.

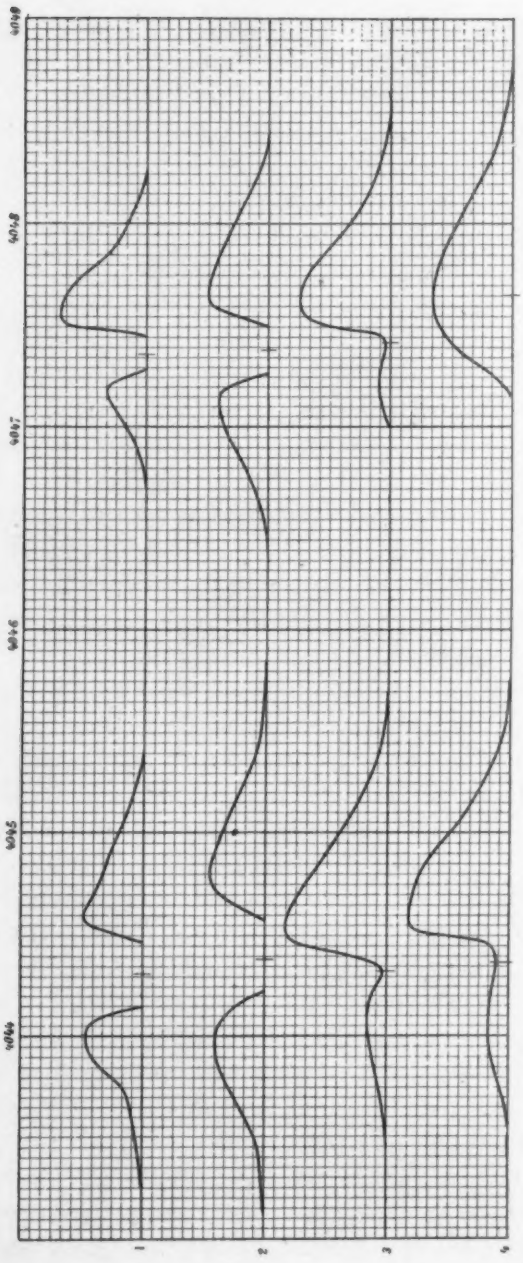
As to the wave-lengths themselves we draw from the table the remarkable result that at smallest concentration—that of 0.2 gram of caustic potash to 100 cu. cm of water—the wave-lengths of lines in the spark are smaller than those in the arc. Judging by Humphrey's results we must then assume that in this case there is about 1.3 atmospheres greater pressure in the arc than in the spark. Again in case of the next higher concentration the wave-lengths of the arc lines are greater than those of the spark lines, although the difference in this case is smaller. Considering the variation of wave-length with density, the table shows a constant increase of the same with increasing concentration. This holds equally for the lines and their reversals. The latter are also displaced. It appears that the wave-length of the reversal is smaller at the critical density than at the smallest density of potassium vapor employed, and further that this density lies higher for the spark than for the arc.

By critical density is meant that density at which the reversal of the line just begins.

Suspicion seems to be justified that the wave-length of the reversal at the critical density agrees perfectly with the least possible wave-length of the line.

The behavior of the lines with the highest concentration in the spark is again of especial interest. At one end (*a*) both lines appear reversed in consequence of the above-mentioned inequality in the amount of moistening of the electrodes in this experiment and resulting distribution of density in the potassium vapor. The reversal is nevertheless entirely unsymmetrical in respect to distribution of wave-lengths and intensity within the line. It appears displaced from the middle toward the violet. The violet component is weak and diffuse, while the red is strong and in sharp contrast at the reversal, gradually weakening toward the side of longer wave-lengths. This is true of both lines. At the lower density, which must be pretty near the critical density for the line $\lambda 4044$, while it is considerably lower for $\lambda 4047$, only the first line is reversed. The location of the reversal cannot be sharply determined, however, as the absorption is not sufficient to produce any considerable difference of intensity between the position of the reversal and the violet component. The line $\lambda 4047$, contrariwise, shows no phenomenon of reversal. The maximum is slightly indicated, and the line is broad and very diffuse, especially toward the red. This line also gives the greatest displacement, 0.295 tenth-meters, as compared with the lowest concentration employed. Corresponding to this the line also exhibits in the arc-spectrum a quite considerable lack of symmetry in the location of the reversal with respect to the middle of the line and in the ratio of intensities of the two components, at a density only slightly above the critical density.

A pictorial representation of these peculiarities is necessary for their comprehension, but a reproduction of the lines themselves, even when much enlarged, is impractical and worthless, as the finer details of these are lost in the necessarily long route from the original to the engraving. We have therefore attempted



1. Arc C = 20; 2. Arc. C = 200; 3. Spark C = 200, lines reversed; 4. Spark C = 200, lines not reversed. The points measured are marked with a vertical line.

to reproduce the character of the lines in the accompanying curves. Of course they do not give us the same result that we should get from the direct enlargement of the original plates. Even with the greatest care in making the drawing, it is impossible to escape from subjective impressions which possibly affect the positions of the edges and the maxima of intensity, etc., less than the estimates of intensity. Measures are hardly possible with the slight breadth, and moreover they would scarcely give us an accurate picture since the changes of intensity with wavelength within a line are very considerable.

The curves are constructed from the screen according to the positions of the maxima, the edges of the reversals and the lines. But the heights of the ordinates which correspond to the intensity of the lines depend on mere estimate. Therefore the corresponding curves of different concentrations in this respect are not comparable with one another; on the other hand the respective vapor densities are quite comparable, especially 3 and 4. In fact the curves were taken from the same plates. It should be further remarked in respect to the arrangement that the wavelength curves are oriented according to convenience. The position of the reading is indicated by a vertical line.

We shall attempt in what follows to find an explanation for the observed facts. We must endeavor therefore to form a conception of the constitution of the luminous vapor. We shall concern ourselves in the next place with the arc. It is clear that when we are considering temperature and density that we must distinguish between the mantle of the arc and its core. The latter is always hotter than the enveloping layers because these are in contact with an environment which is cooler, and by convection and radiation part with a portion of their heat energy. The inner layers on the contrary are shielded and remain at a higher temperature. We have therefore a fall of temperature, although perhaps small, from the inner to the outer regions of the arc. At the same time, moreover, the vapor density is variable in a direction perpendicular to the arc. In the layers at the surface of the mantle small particles diffuse out from the arc, cool off and

contribute little or nothing to the radiation. Especially at small densities is the influence of this shown so that we observe almost solely light from only the interior of the arc. But in all cases the line is composed of an infinite number of lines each of which corresponds to a distinct temperature and density of the luminous vapor.

The superposition of the intensity curves produces those observed, and the character of the line will be influenced most by those intensities which occur most frequently with small variation, these giving the average values. If we increase the concentration and therefore the density of the luminous vapor we will in the first place increase the intensity of the lines because the number of radiating centers is increased. At the same time the breadth of the line increases. Wave-lengths, further, come under observation which at lower temperatures have not figured. The wave-length also increases because as a consequence of greater density and resulting crowding of the particles toward one another, the forces which they mutually exert increase. This damping action is of course greater in the inner portion of the vapor than in the outer. Because, as a result of the higher temperature of the core, the energy of the radiation arising from within is greater than that from without, therefore we observe in the line a wave-length corresponding to a portion of the core. But the relation alters at the critical density.

It is therefore clear that we may regard the resulting intensity curve as having its origin in two, the emission and the absorption curve. Light which has come from the inner portion of the luminous vapor suffers in its passage into all the layers an absorption proportional to its emission.

If this increases to such an extent that a self-reversal is seen, we shall have superposed upon the emission curve of the strongly displaced line which corresponds to the central radiation, the absorption curve of the edge, which, on account of the lower temperature and less density in this region, shows a slighter displacement. Hence the reversal appears unsymmetrical and narrow, corresponding to the relatively low emission of

the edge radiations. The more the density increases, the deeper are the layers of gas which share in the reversal; hence, just so much broader the reversal, and greater the displacement toward the red. Indeed, in the case of layers which lie beneath the critical one, we naturally observe absorption, only we do not then say that the line is self-reversed. In this case the absorption curve, which corresponds to its slighter displacement, lies principally above the violet part of the emission curve, which is therefore weakened toward the red. The line consequently seems to be diffuse toward the red, as is readily understood. In consequence of the absorption, which, of course, in the case of a self-reversal is not limited to that alone, the intensities of the components fall—a conclusion which seems to be supported by experience. The maximum intensity is observed in the vicinity of the critical density. Still more striking than in the case of the arc are the relations in the spark, in which as well the pressure plays a certain part. For the spark the temperature and density differences between the interior and surface are evidently still greater than in the case of the arc.

On the basis of Schuster's investigations I have elsewhere[1] developed the view that the pressure and the temperature of the spark depend to a considerable extent upon the velocity of the particles. It is then clear that at the surface of the spark the motion of translation of the particles, owing to friction with the surrounding gas, must be considerably less than in the interior, where all the particles describe sensibly parallel paths. In addition, therefore, to the fact of the cooling of the gas mantle through the radiations it emits, a cooling found in the arc as well, comes the circumstance that, for the reasons given, the temperature originally has a lower value than in the interior. The fall of temperature is therefore greater than in case of the arc. In consequence of the high pressure prevailing in the interior, the displacement of the line originating from the core is greater than for the arc. But as the fall of density is also

[1] E. HASCHEK, "Druck und Temperatur im elektrischen Funken." *Sitzungsberichte*, etc., **109**, Abth. IIa, 1900.

greater in case of the spark, we observe as the resulting wave-length one corresponding to a less density than when an equal amount of material is introduced into the arc; since the average value of temperature and density at which we observe lies lower for the spark than for the arc, the conditions of the core being assumed to be the same.

This assumption would apply pretty closely in these experiments. Hence the explanation why at low concentrations the wave-length in the spark is smaller than in the arc.

If we now increase the density still lower strata will prevail in the intensity curve, on account of the more rapid increase of their emission. The intensity in the interior will increase in proportion to the number of luminous particles, while at the surface the currents and diffusion will remain the same, the cooling effect of the friction increasing. Larger displacements than in the arc will now appear on account of the interior pressure, since not only the increased density but also the pressure contributes to the closing in of the particles. Hence the emission increases more rapidly from the core than from the outside. Therefore the absorption of the exterior portions will not become effective until later, that is, the critical density will lie higher, as appears to be confirmed by experience. But before this is attained we shall notice in the spark as in the arc the absorption at the violet edge of the line. Since the maximum lies further toward the red for the spark, we shall get very diffuse lines, shaded off toward the red for the same reasons as in case of the arc. This absorption at the violet edge also remains, however, at the critical and higher densities. There should also be observed a weakening of the violet component in addition to the reversal, as is also found in fact.

The above results may be summarized as follows: With increasing density of the luminous vapor, displacements occur both in the arc and spark spectrum. These affect the lines as well as their reversals — a phenomenon due to the constitution of the luminous vapor.

III. ON THE DEPENDENCE OF THE WAVE-LENGTHS UPON THE MODE OF PRODUCTION OF THE LUMINOUS VAPOR.

In the discussion of the effect of the density upon the wave-length in the previous section, we have already emphasized the difference between the arc and spark spectra. We saw that the shift for an equal increase of concentration was greater for the spark than for the arc spectrum. A cause of this was found on the one hand in the pressure developed in the spark, and on the other in the greater contrasts in temperature and density than in the arc. It is therefore clear that all variations in the production of the luminous vapor will be accompanied by corresponding changes in the wave-length of the emitted lines, wholly aside from the changes in the character of the spectrum as a whole.

The above mentioned paper on the pressure in the spark furnishes us a guide for investigation. Indeed all conditions which alter the pressure must exert an influence on the wave-length. The difference in pressure between the transformer and the Ruhmkorff coil is most conspicuous, and is explained by the different consumption of energy. But, moreover, with similar pieces of apparatus differences arise, namely, with variable capacity, and also with the pressure and character of the enveloping gas.

The influence of these last mentioned conditions is clearly shown by J. F. Mohler's[1] paper on "Pressure in the Electric Spark," which I will here briefly review. Mohler worked with an induction coil which without capacity gave a spark of some 20 cm. Measured capacities (from 11.1 to 70.2 meters) were inserted in photographing the spectrum, and the spark length used was 3 mm or less. Cadmium served as electrodes so that in all cases the maximum vapor density was attained. It appeared that the wave-length increased with the capacity employed, from 0.026 tenth-meters, with 11.1 meters capacity, up to 0.088 tenth-meters at 70.2. Unfortunately the measurements for the lines chosen ($\lambda\lambda$ 5086.001, 4800.097, 4678.339) are

[1] J. F. MOHLER, ASTROPHYSICAL JOURNAL, 10, 1899.

not given separately, but merely the mean obtained from the measured values reduced to those at λ 4000. Therefore it is not possible to see whether all the lines were affected in the same way. It is worth noting that the displacement increases at first more rapidly, then more slowly with the capacity, and that it clearly approaches a maximum, just as E. Haschek and H. Mache found to be the case with pressure due to the spark. Therefore it appears that this alone is a determining condition. Mohler investigated the influence of the pressure and the character of the surrounding gas at constant capacity. In the first case he found an increase in shift proportional to the increase of pressure of the surrounding medium. He used carbon dioxide instead of air; the displacement increased in the ratio of 1.38 to 1.

We should here cite also the experiments of J. Wilsing,[1] who caused the spark to pass under water. The shift observed in this case was very marked, reaching in some cases the value of several units.

The comparison of spectra obtained with a Ruhmkorff coil fitted with different interrupters is important. I used an induction coil, which without a condenser gave a spark about 12 cm long between spherical terminals; and employed both the ordinary hammer and the Wehnelt electrolytic interrupter. A condenser battery of about 60 meters capacity was inserted in the secondary circuit. The experiment was performed with a 20 per cent. solution of caustic potash, due regard being paid to the precautionary rules previously given. The following table gives the wave-lengths measured.

It must be noted that in contrast with the lines given by the transformer those here obtained are weak and very diffuse, so that possibly an error of 0.02 tenth-meters may occur. For this reason the wave-length numbers previously given for the high-tension transformer are shortened to two decimals.

	Induction Coil	
Transformer	Wehnelt Break	Hammer Break
4044.38	4044.36	4044.44
4047.45	4047.41	4047.47

[1] J. Wilsing, Astrophysical Journal, 10, 113, 1899.

Therefore it here again appears that the lines are strongly displaced: fairly equally in the case of the Wehnelt break and the transformer, but more strongly with the hammer break. The explanation for this may lie in the fact that with the small number of sparks (about 150 a minute) the air in the region of the spark's path is entirely cooled again, so that a strong fall in temperature is present. The state of things may be analogous to the pressure relations. The discharge has to break its way through the medium afresh. The particles at the periphery are hemmed in very strongly. A strong displacement is therefore observed which corresponds to the maximum pressure, while the mean pressure lies lower. This explanation is favored by the circumstance that the lines are very diffuse, and do not possess an especially well marked intensity maximum.

In closing it may further be noted that with the induction coil the times of exposure were quite considerable; with the hammer break they were 400 seconds; with the Wehnelt break 500, despite the great number of sparks. Therefore, on this account it is not advisable to use this break in photographing spectra. Nevertheless, the numbers given show that we can with full justification apply to the induction coil the wave-lengths obtained with the high potential transformer.

A valuable conclusion relative to the limits of accuracy in measurement may be drawn from the results of this and the previous sections. We have seen that displacements of lines are common to both arc and spark spectra, and under certain conditions attain considerable magnitudes. The spectrum of the spark especially shows strong shifts which reach 0.2 tenth-meters for elements which are rich in lines, but 0.7 tenth-meters for those which have few lines in their spectrum. The observed value of the wave-length is, as was shown, dependent, to a high degree, upon the momentary conditions of the experiment, and these are, in many cases, not at all subject to control. This is seen especially in the case of the density of the luminous vapor. Therefore, in most cases, especially in dealing with the identification of lines, we may satisfy ourselves with an accuracy of

measurement which neglects the shift of the lines, at least as long as the possible variation for every line of every element is unknown. And this task is scarcely capable of execution. If, now, we are to assign a limit of accuracy, 0.03 tenth-meter ought to serve well for elements rich in lines, and 0.1 tenth-meter for those poor in lines. The first set of spectra shows lines easily measurable with an accuracy of 0.03, which generally present little shift; while elements whose spectra are characterized by great shifts give lines which are very broad and not easily measured. These deductions hold, of course, only when the spectra of composite substances are being spectroscopically examined for purposes of identification. In such cases we draw our conclusions from the agreement of a number of lines. But if we are dealing with the change of wave-lengths by external causes, investigating the homogeneity of lines and similar problems — in short, studying lines as such — then we should strive to attain to the greatest possible accuracy of wave-length measurement. However, in these cases, an approximate value of the wave-length will suffice, if only the changes be determined with sufficient sharpness. And this problem is incomparably the easier one.

The question now arises as to how far the measurements of wave-lengths which hold for the transformer spectrum are transferable to spark spectra obtained with the Ruhmkorff coil — a question which cannot, in general, be answered. As shown by the foregoing investigation, the wave-length of the lines is dependent, to a high degree, upon the energy consumed. But the consumption of energy with the transformer is very great; some lines are, therefore, shifted strongly toward the red. The Ruhmkorff coil also gives nearly an equal displacement under conditions like those described above. But the conclusion that in all cases the induction coil and transformer give equal shifts is inadmissible — for example, certainly not with small instruments which are fed with battery or storage-cell currents. Lower values than with the transformer will then obtain for the shifted lines, which will be in any case in the minority. We may

assume, moreover, as a rule, that lines of an element which enter as an impurity are undisplaced; or we may state with more exactness that if the limit of error of measurement be chosen such that it lie in the hundredths place, then the shift is smaller than the error of measurement, and will therefore be concealed. Therefore, we can assume, but with considerable reserve, that the transformer wave-lengths hold true for the Ruhmkorff spectrum, and that considerable differences enter only in cases of small apparatus and for but a few lines. But despite this, errors in the identification of lines can scarcely enter, because a whole series of lines is always considerd and never single lines.

NOTE.—An attempt has been made at the Yerkes Observatory to verify the results obtained by Professor Haschek. In the first instance Professor C. E. St. John and Dr. N. E. Kent used a Littrow spectroscope with 5-inch plane grating, having 20,000 lines to the inch (first order) and combined collimator and camera objective of 18 feet focal length. The large induction coil was supplied with current from a 3-kilowatt alternating dynamo, run at about 1400 revolutions per minute, and giving about 90 complete cycles per second. The capacity of the condenser, which was connected in parallel with the secondary coil, ranged from 0.003 to 0.024 microfarads. In a second series of experiments made by Dr. Kent the second-order spectrum of a 6-inch concave grating having 15,000 lines to the inch was used, and a transformer giving 30,000 volts was substituted for the coil. The capacity of the condenser ranged from 0.007 to 0.07 microfarads. The spectra of arc and spark were in all cases photographed on the same plate. The maximum displacements observed for the titanium lines in Haschek's table did not exceed 0.04 tenth-meter, and are thus much smaller than his values. Whether this lack of agreement is to be attributed to different electrical conditions or to some other cause cannot as yet be determined. It may be remarked, however, that differential measures of arc and spark lines on the same plate might reasonably be expected to yield more accurate results than the method of comparison uesd in the first section of Haschek's article. In view of the importance of the subject, and its bearing upon various astrophysical problems, it is hoped that the experiments will be repeated elsewhere.—ED.

Minor Contributions and Notes

OBSERVATIONS OF THE SPECTROSCOPIC BINARY *η PEGASI*.[1]

THE binary character of *η Pegasi* was discovered in August, 1898, from observations made with the Mills spectroscope, and announced in the ASTROPHYSICAL JOURNAL for October, 1898. It was the first one of some thirty-five spectroscopic binary systems discovered in the past three years with this efficient instrument. As a basis for determining the orbit of the bright component of this system, the following velocities in the line of sight were observed:

No.	Date, Greenwich M. T.			Velocity Kilometers	No.	Date, Greenwich M. T.			Velocity Kilometers
1	1896	August	27.8	+ 7.10	16	1899	June	21.0	− 8.02
2		September	23.7	+ 5.10	17		June	27.0	− 8.31
3	1897	July	8.9	− 6.37	18		July	26.9	− 7.14
4		September	28.7	− 2.21	19		September	6.8	− 6.81
5	1898	August	29.8	+ 16.54	20		December	19.7	− 3.86
6		August	30.8	+ 15.62	21		December	25.7	− 1.44
7		September	4.7	+ 16.46	22	1900	May	14.0	+ 10.89
8		September	15.8	+ 15.74	23		June	7.0	+ 14.06
9		October	18.7	+ 10.99	24		August	1.9	+ 18.89
10		October	24.8	+ 11.51	25		September	25.7	+ 21.40
11		October	26.8	+ 10.83	26		October	9.7	+ 20.37
12		November	28.7	+ 6.06	27		October	24.8	+ 19.88
13	1899	January	23.6	− 0.84	28		December	11.7	+ 15.17
14		May	2.0	− 6.44	29	1901	May	9.0	− 0.18
15		May	9.0	− 5.94					

The period of revolution of the system was early found to be about two years and a quarter. The observations are distributed over more than two complete periods.

The probable error of one observation, ± 0.47 kilometer, determined by Dr. Crawford, is very satisfactory under the circumstances. It is based upon all the observations secured. These include those made in 1896, with a very imperfect camera lens. The first thirteen observations were obtained before the special temperature control was installed.

[1] *Lick Observatory, University of California, Bulletin* No. 5.

The thirteenth observation was made when the star was low in the west, in the early evening, with the temperature changing rapidly. Experience has shown that observations taken under such conditions are not only useless, but are apt to be harmful, and No. 13 might well have been rejected. It furnishes the largest residual, and its rejection would have reduced very materially the computed probable error of a single observation.

The spectra were measured, in all cases, soon after they were secured, in six different years. The 26th, 27th, and 28th plates were measured and reduced by Dr. Reese, and the remaining twenty-six plates by myself. If they could have been measured in quick succession, by one observer, no doubt the results would yield a much smaller computed probable error, as the personal habits of measurement change appreciably with time.

Messrs. Hussey and Aitken have carefully examined η *Pegasi* with the 36-inch refractor, but have been unable to detect the companion star.

W. W. CAMPBELL.

1901, July 24.

THE ORBIT OF THE SPECTROSCOPIC BINARY η *PEGASI.*

This orbit of η *Pegasi* is based upon the twenty-nine observations given above by Director Campbell. Of these, several groups have been formed into normal positions by taking the mean of their dates and of their velocities. These groups are Nos. 5, 6, 7, 8; 9, 10, 11; 14, 15; 16, 17; and 20, 21. To these will be given the numbers N_1, N_2, etc. Their data are as follows:

No.	Date, Greenwich M. T.	Velocity Kilometers.	Wt.
N_1	1898 September 4.8	+ 16.09	4
N_2	October 23.4	+ 11.11	3
N_3	1899 May 5.5	− 6.19	2
N_4	June 24.0	− 8.16	2
N_5	December 22.7	− 2.65	2

All of the other observations have been given weight unity, except No. 13, to which, for reasons given by Director Campbell, weight one-half has been assigned.

From the plot of these observations the first approximation to the period was taken to be 815 days. By adjusting the upper and the

lower areas to equality by means of a planimeter, the velocity of the center of mass of the system was found to be + 4.15 km.

Using the formulæ and notation of Lehmann-Filhés, the following preliminary constants and elements have been obtained:

PRELIMINARY ELEMENTS.

$A = 16.85$ km $\qquad B = 12.05$ km

$\varepsilon_1 = +0.429 \qquad \varepsilon_2 = -0.482$

$K = 14.45$

$e = 0.176$

$\omega = 19^\circ.056$

$\mu = 0^\circ.007709$ rad.

$= 0^\circ.4417$

$T =$ 1898, Aug. 3.0

$V_0 = +4.15$ km

$U = 815.0$ days

$a \sin i = 159,420,000$

$[pvv]_n = 19.55$

The residuals resulting from these elements are given in the table at the end. From these elements and the residuals, the following twenty-one weighted, homogeneous observation equations were set up:

No.	a	b	c	d	e	f	n
1.....	0.254 u	−1.443 v	−1.522 w	+1.223 x	+1.337 y	+1.000 z	+0.720=0
2.....	0.014	−1.580	−1.511	+1.081	+1.228	+1.000	−0.750=0
3.....	−0.744	+1.258	+0.517	−0.167	−0.330	+1.000	−0.220=0
4.....	−0.464	+0.235	+1.039	−0.262	−0.656	+1.000	−0.350=0
N_1 ...	1.866	+1.256	−2.020	−0.086	+2.032	+2.000	+3.080−0
N_2 ...	0.900	−1.552	−2 481	−0 247	+2.339	+1.730	+0.969=0
12....	0.182	−1.521	−1.528	−0.200	+1.312	+1.000	+0.720=0
13....	−0.192	−0.896	−0.977	−0.143	+0.711	+0.707	+0.749=0
N_3 ...	−1.056	+0.834	−0.949	−0.182	+0.510	+1.414	−0.650=0
N_4 ...	−1.168	+1.714	−0.376	−0.062	+0.148	+1.414	+0.537=0
18....	−0.832	+1.409	+0.003	+0.022	−0.048	+1.000	−0.730=0
19....	−0.792	+1.399	+0.331	+0.118	−0.227	+1.000	−0.490=0
N_5 ...	−0.656	+0.332	+1.509	+0.609	−0.928	+1.414	+0.127=0
22....	0.444	−1.487	+1.309	+0.927	−1.101	+1.000	−0.460=0
23....	0.617	−1.303	+1.207	+0.954	−1.092	+1.000	−0.990=0
24....	0.997	−0.028	+0.721	+0.752	−0.804	+1.000	−0.330=0
25....	1.166	+1.349	−0.061	+0.025	−0.024	+1.000	−0.400=0
26....	1.156	+1.452	−0.284	−0.231	+0.223	+1.000	+0.490=0
27....	1.119	+1.390	−0.521	−0.516	+0.489	+1.000	+0.440=0
28....	0.836	+0.213	−1.156	−1.290	+1.155	+1.000	+1.060=0
29....	−0.404	−0.936	−1.270	−1.139	+0.870	+1.000	−1.510=0

Where $u = \delta K$; $v = 10\,\delta e$; $w = 10\,\delta\omega$; $x = 10{,}000\,\delta\mu$; $y = \frac{1}{10}\delta T$; and $z = \delta V_0$.

From these equations the following normal equations result (the coefficients are given by their logarithms):

1	1.198822 u	+0.322426n v	+0.817499n w	+9.397940 x	+0.809492 y	+0.665675 z	+0.955303 = 0
2	0.322426n	+1.501004	+0.756408	+0 760875n	+0.670060n	+0.565021	+0.544068 = 0
3	0.817499n	+0.756408	+1.475599	+0.673021	+1.405858n	+1.060244n	+1.084219n = 0
4	9.397940	+0.760875n	+0.673021	+0.950754	+0.609914n	+0.046495	+0.320977n = 0
5	0.809492	+0.670060n	+1.405858n	+0.609914n	+1.348110	+1.023828	+1.087320 = 0
6	0.665675	+0.565021	+1.060244n	+0.046495	+1.023828	+1.454692	+0.747179 = 0

The solution of these gives

δK	$= -0.29$ km	± 0.12 km
δe	$= -0.0264$	± 0.0091
$\delta \omega$	$= -11^{\circ}143$	$\pm 2^{\circ}822$
$\delta \mu$	$= -0.000023$ rad.	± 0.000018 rad.
	$= -0^{\circ}00132$	$\pm 0^{\circ}00101$
δT	$= -28.6$ days	± 5.9 days
$\delta V_{\circ}$	$= +0.17$ km	± 0.10 km
δU	$= +2.4+$ days	± 1.9 days

For these corrections the following elements result:

SECOND ELEMENTS.

K	$= 14.16$ km
e	$= 0.1496$
ω	$= 7^{\circ}913$
μ	$= 0.007686$ rad,
	$= 0^{\circ}44038$
T	$= 1898$, July 5.4
$V_{\circ}$	$= +4.32$ km
U	$= 817.4+$ days

$[pvv]_n = 6.05$ from the observation equations. The probable errors given above were obtained from this $[pvv]_n$.

$[pvv]_n = 6.55$ from the ephemeris residuals.

$[pvv] = 11.33$.

NOTE.—$[pvv]_n$ means the $[pvv]$ resulting from using the residuals from the normal places instead of from the individual observations. When the latter are used no subscript will appear with the symbol $[pvv]$.

The resulting probable error of a single observation is:

$r = \pm 0.43$ km from the first $[pvv]_n$.

$r = \pm 0.474$ km from $[pvv]$.

The velocities and the corresponding residuals computed from these elements are shown in the table at the end. This table gives also the differences between the residuals as found from the elements and from the observation equations. This column is headed Δ_1. From these differences it is seen that the terms involving the second powers of the increments in the differential equations of condition are not negligible. This discrepancy necessitated another solution, starting from the second element.

From these elements the following weighted, homogeneous observation equations result:

No.	a	b	c	d	e	f	n
1	0.212u	−1.472v	−1.442w	+1.049x	+1.192y	+1.000z	+0.230=0
2	−0.007	−1.455	−1.428	+0.935	+1.106	+1.000	−0.880=0
3	−0.766	+1.113	+0.537	−0.155	−0.330	+1.000	−0.160=0
4	−0.470	−0.092	+1.084	−0.256	−0.705	+1.000	−0.120=0
N_1	1.730	+0.266	−2.034	−0.158	+1.972	+2.000	+0.940=0
N_2	0.826	−1.931	−2.366	−0.321	+2.101	+1.732	−0.052=0
12	0.167	−1.492	−1.445	−0.224	+1.179	+1.000	+0.630=0
13	−0.182	−0.713	−0.936	−0.176	+0.669	+0.707	+1.075=0
N_3	−1.046	+0.966	−0.960	−0.223	+0.563	+1.414	+0.042=0
N_4	−1.181	+1.769	−0.402	−0.097	+0.211	+1.414	+0.919=0
18	−0.852	+1.406	−0.015	+0.004	−0.008	+1.000	−0.600=0
19	−0.820	+1.327	+0.323	+0.113	−0.203	+1.000	−0.490=0
N_5	−0.682	−0.068	+1.513	+0.683	−0.980	+1.414	+0.198=0
22	0.490	−1.301	+1.302	+0.992	−1.125	+1.000	+0.370=0
23	0.677	−0.910	+1.172	+0.982	−1.075	+1.000	−0.150=0
24	1.034	+0.575	+0.627	+0.647	−0.657	+1.000	+0.070=0
25	1.145	+1.417	−0.147	−0.131	+0.124	+1.000	−0.870=0
26	1.121	+1.336	−0.354	−0.367	+0.341	+1.000	−0.170=0
27	1.073	+1.109	−0.567	−0.614	+0.561	+1.000	−0.360=0
28	0.788	−0.178	−1.117	−1.235	+1.067	+1.000	+0.310=0
29	−0.371	−0.802	−1.239	−1.149	+0.581	+1.000	−0.760=0

Where, as before, $u=\delta K$; $v=\delta e$; $w=10\,\delta\omega$; $x=10{,}000\ \delta\mu$; $y=\frac{1}{10}\delta T$; and $z=\delta V_0$. From these equations the following normal equations were computed (coefficients logarithmic).

1	1.181433u	+0.590730n v	+0.783868n w	+9.398808n x	+0.759441 y	+0.609594z	+9.680789 =0
2	0.590730n	+1.453624	+0.886378	+0.635685n	+0 798547n	+0.015360	+0.308137n=0
3	0.783868n	+0.886378	+1.454387	+0.765929	+1.372258n	+1.053981n	+0.283075n=0
4	9.398808n	+0.635685n	+0.765929	+0.932068	+0.704751n	+9.033424	+9.155336 =0
5	0.759441	+0.798547n	+1.372258n	+0.704751n	+1.299202	+1.003590	+0.252125 =0
6	0.609594	+0.015360	+1.053981n	+9.033424	+1.003590	+1.454799	+0.093071 =0

The solution of these gives:

δK	= +0.04 km	± 0.12 km	± 0.13 km
δe	= +0.0052	± 0.0098	± 0.0106
$\delta\omega$	= − 2°.308	± 3°.430	± 3°.708
$\delta\mu$	= − 0.000005 rad.	± 0.000019 rad.	± 0.000020 rad.
	= − 0°.00029	± 0°.00108	± 0°.00117
δT	= − 5.7 days	± 7.5 day	± 8.1 days
δV_0	= − 0.01 km	± 0.10 km	± 0.10 km
δU	= +0.5 days	± 2.0 days	± 2.2 days

$[pvv]_n = 6.21$

$[pvv] = 11.13$

$r = \pm 0.43$ from $[pvv]_n$

$r = \pm 0.469$ from $[pvv]$

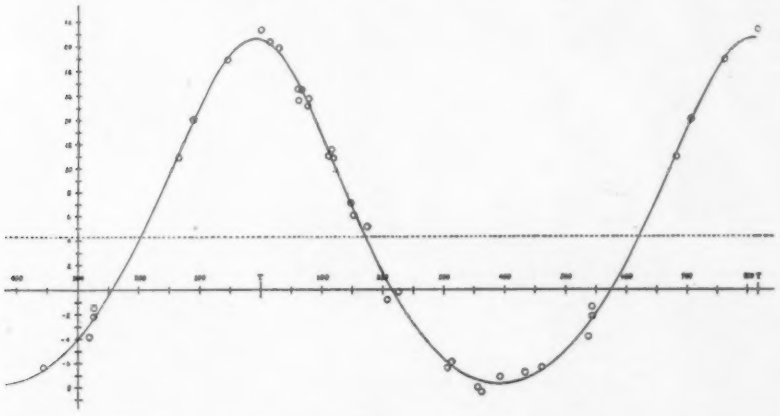
The first set of probable errors given after the corrections to the elements has been derived from the first r; the second set from the second r. The latter, depending upon the residuals from the individual observations, is the more reliable.

Applying these corrections to the second elements given above, the following final elements result:

FINAL ELEMENTS.

K = 14.20 km	± 0.13 km
e = 0.1548	± 0.0106
ω = 5°.605	± 3°.708
μ = 0.007681 rad.	± 0.000020 rad.
= 0°.44009	± 0°.00117
T = 1898, June 29.7	± 8.1 days
= 1900, Sept. 25.7	
V_0 = + 4.31 km	± 0.10 km
U = 818.0 days	± 2.2 days
$a \sin i$ = 157,800,000	

The velocities and the corresponding residuals computed from these elements are shown in the table at the end. The differences



between the residuals as found from these elements and from the observation equations are placed in the column Δ_0. They show this final solution to be satisfactory.

The curve in the accompanying figure is that of the final elements. The observations are represented by the small circles. The intervals

shown on the X axis are fifty days. The zero is at the place representing the time of periastron (T). One division on the Y axis represents a velocity of one kilometer per second. The dotted line indicates the velocity of the eentcr of mass of the system. The maximum velocity is +20.70 km per second and the minimum is −7.70 km per second.

TABLE.

No.	V	Wt.	Elements—I.		Elements—II.		Δ_1	Elements—III.		Δ_2
			V	O.—C.	V	O.—C.		V	O.—C.	
	km. sec.		km. sec.	km. sec.	km. sec.	km. sec.		km. sec.	km. sec.	
1	+ 7.10	1	+ 7.82	−0.72	+ 7.33	−0.23	0.18	+ 7.10	±0.00	0.00
2	+ 5.10	1	+ 4.35	+0.75	+ 4.22	+0.88	0.11	+ 4.04	+1.06	0.01
2	− 6.37	1	− 6.59	+0.22	− 6.53	+0.16	0.02	− 6.57	+0.20	0.04
4	− 2.21	1	− 2.56	+0.35	− 2.33	+0.12	0.07	− 2.39	+0.18	0.01
5	+16.54	1	.....	.....	+17.14	−0.60	...	+17.03	−0.49	...
6	+15.62	1	.....	.....	+17.04	−1.42	...	+16.93	−1.31	...
7	+16.46	1	.....	.....	+16.57	−0.11	...	+16.45	+0.01	...
N_1	+16.09	4	+17.63	−1.54	+16.56	−0.47	0.12	.....	.....	0.04
8	+15.74	1	.....	.....	+15.44	+0.30	...	+15.19	+0.55	...
9	+10.99	1	.....	.....	+11.65	−0.66	...	+11.47	−0.48	...
N_2	+11.11	3	+11.67	−0.56	+11.08	+0.03	0.21	.....	.....	0.01
10	+11.51	1	.....	.....	+10.91	+0.60	...	+10.73	+0.78	...
11	+10.83	1	.....	.....	+10.67	+0.16	...	+10.48	+0.35	...
12	+ 6.06	1	+ 6.78	−0.72	+ 6.69	−0.63	0.13	+ 6.53	−0.47	0.00
13	− 0.84	½	+ 0.22	−1.06	+ 0.68	−1.52	0.01	+ 0.62	−1.46	0.00
14	− 6.44	1	.....	.....	− 6.02	−0.42	...	− 5.97	−0.47	...
N_3	− 6.19	2	− 6.65	+0.46	− 6.16	−0.03	0.05	.....	.....	0.00
15	− 5.94	1	.....	.....	− 6.30	+0.36	...	− 6.25	+0.31	...
16	− 8.02	1	.....	.....	− 7.46	−0.56	...	− 7.41	−0.61	...
N_4	− 8.16	2	− 7.78	−0.38	− 7.51	−0.65	0.05	.....	.....	0.00
17	− 8.31	1	.....	.....	− 7.55	−0.76	...	− 7.50	−0.81	...
18	− 7.14	1	− 7.87	+0.73	− 7.74	+0.60	0.04	− 7.70	+0.56	0.00
19	− 6.81	1	− 7.30	+0.49	− 7.30	+0.49	0.01	− 7.29	+0.48	0.00
20	− 3.86	1	.....	.....	− 2.71	−1.15	...	− 2.80	−1.06	...
N_5	− 2.65	2	− 2.56	−0.09	− 2.51	−0.14	0.10	.....	.....	0.00
21	− 1.44	1	.....	.....	− 2.30	+0.86	...	− 2.39	+0.95	...
22	+10.89	1	+10.43	+0.46	+11.26	−0.37	0.01	+11.27	−0.38	0.00
23	+14.06	1	+13.07	+0.99	+13.01	+0.15	0.05	+13.98	+0.08	0.01
24	+18.89	1	+18.56	+0.33	+18.96	−0.07	0.22	+19.12	−0.23	0.01
25	+21.40	1	+21.00	+0.40	+20.53	+0.87	0.13	+20.63	+0.77	0.00
26	+20.37	1	+20.86	−0.49	+20.20	+0.17	0 08	+20.27	+0.10	0.00
27	+19.88	1	+20.32	−0.44	+19.52	+0.36	0.01	+19.55	+0.33	0.00
28	+15.17	1	+16.23	−1.06	+15.48	−0.31	0.14	+15.40	−0.23	0.00
29	− 0.18	1	− 1.69	+1.51	− 0.94	+0.76	0.03	− 0.92	+0.74	0.01

RUSSELL TRACY CRAWFORD.

July 24, 1901.

OPPOSITION OF *EROS* (433) IN 1903.[1]

THE planet *Eros* is now so near the Sun that further observations of its light have become impossible. At the same time sufficient material has not been accumulated since the discovery of its variation in light, to determine satisfactorily the laws governing it. It is, therefore, a matter of no little interest to learn when further observations can be obtained. Since three times the tropical period is about seven years, the favorable conditions of 1893 and 1900 will not recur until 1907. The next oppostion will occur in 1903, under conditions similar to those in 1896. The planet was then so far south that had its existence been known at that time it could not have been observed

TABLE I

COMPUTED POSITIONS.

J. D.	Date 1901-3			R. A. 1900		Dec. 1900		log r	log Δ
	y	m	d	h	m				
5501	01	4	26	8	39.1	— 0°	38′	0.1025	9.8251
5506		5	1	8	54.7	— 1	41	0.1076	9.8447
5516		5	11	9	25.2	— 3	44	0.1179	9.8841
5556		6	20	11	20.4	—11	23	0.1587	0.0340
5596		7	30	13	7.4	—18	11	0.1939	0.1657
5636		9	8	14	51.6	—23	24	0.2208	0.2732
5676		10	18	16	36.6	—25	59	0.2391	0.3543
5716		11	27	18	21.1	—25	2	0.2491	0.4085
5745		12	26	19	34.3	—21	59	0.2512	0.4310
5800	02	2	19	21	44.4	—11	21	0.2435	0.4364
5840		3	31	23	13.7	— 0	44	0.2281	0.4116
5880		5	10	0	45.7	+11	10	0.2041	0.3658
5920		6	19	2	31.4	+22	49	0.1717	0.3034
5960		7	29	4	44.7	+30	58	0.1323	0.2360
6000		9	7	7	24.1	+29	56	0.0914	0.1653
6040		10	17	9	56.7	+16	59	0.0610	0.1149
6080		11	27	12	8.3	— 2	48	0.0560	0.0796
6160	03	2	14	16	3.5	—33	57	0.1188	0.0251
6200		3	26	17	38.2	—40	43	0.1596	9.9540
6240		5	5	18	4.9	—44	38	0.1945	9.8539
6250		5	15	17	53.4	—45	0	0.2020	9.8331
6260		5	25	17	36.0	—44	43	0.2090	9.8197
6280		6	14	16	52.7	—41	24	0.2213	9.8276
6300		7	4	16	24.6	—35	54	0.2314	9.8832
6310		7	14	16	20.0	—33	18	0.2357	9.9221
6320		7	24	16	20.9	—31	5	0.2395	9.9642
6360		9	2	17	1.2	—25	55	0.2493	0.1252
6400		10	12	18	12.4	—23	3	0.2509	0.2475
6440		11	21	19	36.6	—19	1	0.2444	0.3294

[1] *Harvard College Observatory Circular* No. 61.

readily, either in the United States or Europe. It accordingly becomes important to trace the path for the next two or three years. The positions have been computed by Miss Anna Winlock by means of the elements given by Millosevich (*A. N.*, 155, 25) for the dates with the results given above :

The intervals between these dates are so large, in some cases, that interpolation by the usual method is impossible. Moreover, only approximate positions are needed, since for a large portion of the time *Eros* will probably be too faint to be observed. To show the general form of its path, so as to prepare plans for observing it, the approximate ephemeris, given in Table II, has been determined graphically for every ten days. After trying various methods, curves were drawn, with Julian Days as abscissas, and ordinates equal to the four tabular quantities given in Table I. For each of these curves, the ordinate for every ten days was next read. First differences were taken, and points again plotted, with these differences, on a much larger scale, as ordinates. A smooth curve was drawn through these points, and the ordinates again read. Regarding these last readings as first differences, the original ordinates were approximately reproduced by successive summations. We thus obtain an ephemeris in which the accidental errors are very small, but which may differ systematically from the computed values, if the curve of first differences is drawn too high or too low. This systematic error was corrected by plotting points with abscissas equal to the Julian Day, and ordinates equal to the difference between the computed values and those given by the approximate ephemeris. These points should lie on a smooth curve, whose ordinates serve to correct the approximate ephemeris. In this way, we obtain an ephemeris, passing through all the computed points, in which the accidental errors are small. Systematic errors may enter between the computed points, since these portions of the curve are necessarily indeterminate, The results are given in Table II, the last column giving the magnitude, uncorrected for phase and assuming, as in *Circular* No. 49, that the magnitude at distance unity is 11.39.

It will be noticed that the earliest favorable time for observation is in the spring of 1903. It is expected that Professor Bailey will make an extensive series of photometric measures of *Eros* during this period at the Arequipa Station.

TABLE II.

APPROXIMATE EPHEMERIS OF *EROS*.

J. D.	Date 1901			R. A. 1900		Dec. 1900	log r	log Δ	Mag.
	y	d	m	h	m				
5500	01	4	25	8	36	— 0°.4	0.102	9.821	11.01
5510		5	5	9	7	— 2.5	0.112	9.860	11.25
5520		5	15	9	37	— 4.5	0.122	9.899	11.49
5530		5	25	10	6	— 6.6	0.131	9.937	11.73
5540		6	4	10	35	— 8.5	0.141	9.974	11.97
5550		6	14	11	3	—10.3	0.151	0.011	12.20
5560		6	24	11	31	—12.1	0.162	0.047	12.43
5570		7	4	11	58	—13.8	0.172	0.081	12.65
5580		7	14	12	25	—15.5	0.181	0.114	12.87
5590		7	24	12	52	—17.2	0.189	0.146	13.07
5600		8	3	13	18	—18.8	0.197	0.176	13.25
5610		8	13	13	44	—20.3	0.204	0.204	13.43
5620		8	23	14	10	—21.6	0.211	0.231	13.60
5630		9	2	14	36	—22.7	0.217	0.257	13.76
5640		9	12	15	2	—23.7	0.223	0.281	13.91
5650		9	22	15	28	—24.5	0.228	0.303	14.05
5660		10	2	15	54	—25.1	0.233	0.323	17.17
5670		10	12	16	20	—25.6	0.237	0.342	14.29
5680		10	22	16	47	—25°.9	0.240	0.360	14.39
5690		11	1	17	13	—26.1	0.243	0.376	14.49
5700		11	11	17	40	—25.9	0.245	0.390	14.57
5710		11	21	18	6	—25.6	0.247	0.402	14.63
5720		12	1	18	32	—25.0	0.249	0.413	14.70
5730		12	11	18	58	—24.1	0.250	0.422	14.75
5740		12	21	19	24	—22.9	0.250	0.429	14.79
5750		12	31	19	49	—21.5	0.250	0.434	14.81
5760	02	1	10	20	14	—19.8	0.249	0.437	14.82
5770		1	20	20	38	—18.0	0.248	0.439	14.83
5780		1	30	21	2	—16.0	0.247	0.439	14.82
5790		2	9	21	23	—13.7	0.246	0.438	14.81
5800		2	19	21	44	—11.3	0.244	0.436	14.79
5810		2	29	22	16	— 8.8	0.241	0.433	14.76
5820		3	11	22	28	— 6.2	0.238	0.427	14.71
5830		3	21	22	51	— 3.5	0.233	0.420	14.65
5840		3	31	23	14	— 0.7	0.228	0.412	14.59
5850		4	10	23	37	+ 2.2	0.224	0.402	14.52
5860		4	20	0	0	+ 5.2	0.219	0.391	14.44
5870		4	30	0	23	+ 8.2	0.213	0.379	14.35
5880		5	10	0	47	+11.2	0.204	0.366	14.25
5890		5	20	1	11	+14.1	0.197	0.351	14.13
5900		5	30	1	36	+17.0	0.190	0.335	14.01
5910		6	9	2	3	+20.0	0.181	0.319	13.89
5920		6	19	2	31	+22.8	0.172	0.303	13.77
5930		6	29	3	3	+25.4	0.162	0.287	13.63
5940		7	9	3	36	+27.7	0.152	0.270	13.50
5950		7	19	4	10	+29.6	0.142	0.253	13.37
5960		7	29	4	45	+31.0	0.132	0.236	13.23
5970		8	8	5	23	+31.7	0.121	0.218	13.09
5980		8	18	6	4	+31.8	0.111	0.199	12.94
5990		8	28	6	45	+31.2	0.101	0.181	12.80

TABLE II—*Continued.*

J. D.	Date 1901–3			R. A. 1900		Dec. 1900	log r	log Δ	Mag.
	y	m	d	h	m				
6000		9	7	7	24	+29.9	0.091	0.165	12.67
6010		9	17	8	3	+27.8	0.082	0.151	12.55
6020		9	27	8	42	+25.0	0.074	0.138	12.45
6030		10	7	9	20	+21.3	0.067	0.126	12.35
6040		10	17	9	57	+17.0	0.061	0.115	12.27
6050		10	27	10	32	+12.3	0.057	0.105	12.20
6060		11	7	11	5	+ 7.3	0.055	0.095	12.14
6070		11	17	11	37	+ 2.3	0.054	0.087	12.09
6080		11	27	12	8	− 2.8	0.056	0.080	12.07
6090		12	6	12	39	− 7.9	0.060	0.074	12.06
6100		12	16	13	9	−12.9	0.066	0.068	12.06
6110		12	26	13	39	−17.5	0.073	0.062	12.07
6120	03	1	5	14	9	−21.7	0.081	0.056	12.07
6130		1	15	14	38	−25.5	0.090	0.050	12.09
6140		1	25	15	7	−28.8	0.099	0.043	12.10
6150		2	4	15	35	−31.5	0.109	0.035	12.11
6160		2	14	16	3	−34.0	0.119	0.025	12.11
6170		2	24	16	30	−36.1	0.129	0.013	12.11
6180		3	6	16	55	−37.9	0.140	9.997	12.07
6190		3	16	17	18	−39.4	0.150	9.977	12.03
6200		3	26	17	38	−40.7	0.160	9.954	11.96
6210		4	5	17	54	−42.0	0.169	9.929	11.88
6220		4	15	18	5	−43.1	0.178	9.903	11.79
6230		4	25	18	9	−44.0	0.186	9.878	11.71
6240		5	5	18	5	−44.6	0.194	9.854	11.63
6250		5	15	17	54	−45.0	0.202	9.833	11.57
6260		5	25	17	36	−44.7	0.209	9.820	11.54
6270		6	4	17	14	−43.5	0.215	9.817	11.55
6280		6	14	16	53	−41.4	0.221	9.828	11.63
6290		6	24	16	36	−38.8	0.226	9.850	11.77
6300		7	4	16	25	−35.9	0.231	9.883	11.96
6310		7	14	16	20	−33.3	0.236	9.922	12.18
6320		7	24	16	21	−31.1	0.240	9.964	12.41
6330		8	3	16	27	−29.4	0.243	0.006	12.63
6340		8	13	16	36	−27.9	0.245	0.047	12.85
6350		8	23	16	47	−26.7	0.247	0.087	13.06
6360		9	2	17	1	−25.9	0.249	0.125	13.26
6370		9	12	17	17	−25.4	0.250	0.159	13.43
6380		9	22	17	34	−24.7	0.251	0.191	13.60
6390		10	2	17	52	−33.9	0.251	0.221	13.75
6400		10	12	18	12	−23.0	0.251	0.248	13.89
6410		10	22	18	32	−22.1	0.250	0.272	14.01
6420		11	1	18	53	−21.1	0.249	0.294	14.10
6430		11	11	19	15	−20.1	0.247	0.313	14.19
6440		11	21	19	37	−19.0	0.244	0.329	14.25

EDWARD C. PICKERING.

AUGUST 10, 1901.

THE INFERIOR CONJUNCTION OF *MERCURY* ON NOVEMBER 4, 1901.

In many popular astronomies a transit of *Mercury* is predicted for the 4th of November of this year. There actually will occur, however, only a close approach of the limbs of *Mercury* and the Sun, at the small distance of 165″, or one-twelfth of the Sun's diameter. It is not impossible that Mercury will be projected upon some prominences happening to be at the necessary position angle, although they would have to be of four times the average height, and would have to be detected by a prominence spectroscope or a spectroheliograph. Since the greatest elevation at which prominences have been observed is 11′ 28″, so far as I know (*A. N.* 3335), it has seemed to me to be sufficient to compute the relative co-ordinates for every ten minutes of the time that the distance of *Mercury* is less than 7′ from the Sun.

Berlin M. T.	Mercury-Sun		Distance of Centers	Equat. Pos. Ang. of Mercury	Distance of Limbs
	Δα	Δδ			
h m	s				
4 50	+16.12	−23′ 6.″9	1406.″3	170.°46	433.″3
5 0	12.49	22 40.9	1372.8	172.45	399.8
10	8.86	14.8	1341.0	174.52	368.0
20	5.23	21 48.7	1310.9	176.69	337.9
30	+1.61	22.6	1282.8	178.96	309.8
40	−2.02	20 56.5	1256.8	181.33	283.8
50	5.64	30.4	1233.1	183.79	260.1
6 0	9.27	4.3	1211.7	186.35	238.7
10	12.90	19 38.2	1192.9	188.99	219.9
20	16.52	12.1	1176.6	191.71	203.6
30	20.15	18 46.1	1163.2	194.50	190.2
40	23.77	20.0	1152.4	197.35	179.4
50	27.40	17 53.9	1144.6	200.24	171.6
7 0	31.02	27.8	1139.7	203.17	166.7
10	34.64	1.8	1137.9	206.11	164.9
20	38.27	16 35.7	1139.1	209.06	166.1
30	41.89	9.6	1143.2	211.99	170.2
40	45.51	15 43.5	1150.2	214.89	177.2
50	49.14	17.4	1160.3	217.75	187.3
8 0	52.76	14 51.4	1173.2	220.55	200.2
10	56.38	25.3	1188.7	223.29	215.7
20	60.01	13 59.2	1207.0	225.95	234.0
30	63.63	33.1	1227.7	228.53	254.7
40	67.25	7.1	1250.9	231.01	277.9
50	70.87	12 41.0	1276.3	233.40	303.3
9 0	74.49	14.9	1303.8	235.69	330.8
10	78.11	11 48.8	1333.3	237.88	360.3
20	81.73	22.7	1364.7	239.98	391.7
30	−85.35	−10 56.7	1397.8	241.98	424.8

The solar radius has been taken as 968".04 and that of *Mercury* as 4".97. Geocentric conjunction occurs at $7^h\ 11^m$, at a distance of 164".9 and position angle 206°.41. As the difference in the equatorial horizontal parallax of the two stars amounts to only 4".17, it is not necessary to take its effect into account in arranging observations. The only stations for observations are the two halves of the American continent, aside from the Cape, where the event occurs at sunset.

It is quite improbable that the phenomenon will actually be observed, for, in the first place, we must assume prominences of unusual height, the average elevation being hardly over 40", and, again, solar activity is at present very slight, although increasing. The above equatorial position angles are reduced to ecliptical by the subtraction of 17°.77, so that *Mercury* will pass not far from the south pole of the Sun, in ecliptical position angle 189°.34. Prominences are only very seldom observed near the poles, although not impossible, and the motion in position angle is rapid, and soon after the closest approach *Mercury*, without moving away very far from there, reaches positions where prominences occur more frequently than at the pole.

It is therefore to be hoped that the regular observers of prominences will especially look out for the region of position angle as situated on November 4. If a prominence of the necessary elevation is situated there, a beginning may be made with the observations, which would be interesting enough. It is regrettable that we are not yet able to observe at any desired time the solar corona, on which *Mercury* would certainly be projected.

F. RISTENPART.

BERLIN, August 14, 1901.

PUBLICATION OF A NEW CATALOGUE OF VARIABLE STARS.

THE council of the *Astronomischen Gesellschaft* has decided upon the publication of a new catalogue of variable stars, and has assigned the work of its preparation to the committee named below.

Observers of variable stars are requested to promptly publish their more extensive, unpublished series of observations, which may be of service in improving the elements, or to communicate regarding them with the executive member of the committee, Professor G. Müller, Kgl. Observatorium, Potsdam, Germany.

The committee also announces that it will from now on assume the assignment of definitive designations to new variables, as soon as their variation is established. A list of the names of the variables discovered in recent years but so far undesignated will be soon published.

THE COMMITTEE:
MESSRS. DUNÉR, HARTWIG, MÜLLER, OUDEMANS.

A CORRECTION.

IN the formulae on page 247 of Volume XI of this JOURNAL, p and q denote the ratios of the *radii* of the two stars to the semi-axis of the orbit. My attention has been called by a friend to the fact that Mr. Roberts has denoted by the same letters the ratios of the *diameters* of the star's semi-axis of the orbit. Consequently the numerical coefficient 0.0092 employed by Mr. Roberts must be acknowledged to be entirely correct.

H. SEELIGER.

MUNICH, July 21, 1901.

CONCERNING THE PAPER "ON THE ABSORPTION SPECTRUM OF CHLORINE."[1]

By ELIZABETH R. LAIRD.

OWING to lack of time, some desired changes could not be made in my paper on the above subject before it went to press, and I would therefore call attention to some explanations and corrections.

In Table I, the same symbol "s" is used in the first column to denote that some of the measurements were made on Sun plates, and in the third to signify sharp. "Band" in Table I, means a line broader than one marked very broad, consisting probably of two or more lines.

The second sentence on page 107 refers to the fact that the fluted appearance is not due to a regular grading in the width or intensity of the lines. The flutings were not observed in the second order spectrum.

In the summary of results, the last three conclusions are based not on the present investigation only, but on a comparison with what seemed to be proper inferences from the work of Hasselberg.

[1] ASTROPHYSICAL JOURNAL, 14, 85, 1901.

ERRATA.

On page 86, line 15, for "fine" read "five."
On page 87, footnote 4, for "106" read "105."
On page 91, line 10, for "with 0.0007 in." read "width 0.007 in."
On page 92, line 12, for "or" read "and."
On page 92, line 34, for "Ballei" read "Baccei."
On page 96, line 24, column 8, for "3" read "4."
On page 96, line 27, column 4, for ".003" read ".008."
On page 96, line 43, column 6, for "4956.647" read "4856.647."
On page 101, line 18, column 5, for "2" read "3."
On page 102, line 47, column 5, for "3" read "6."
On page 103, line 34, column 6, for "5214.051" read "5215.051."
On page 106, line 11, omit "especially."
On page 107, line 20, for "line of spectrum" read "line spectrum."
On page 109, line 8, for ".So" read ",so."
On page 115, line 4, for "MacKenzie" read "Mackenzie."

SEPTEMBER, 1901.

PLATE VIII.

N.

S.

CENTRAL PARTS OF THE GREAT NEBULA IN *ANDROMEDA*.
PHOTOGRAPHED WITH THE TWO-FOOT REFLECTOR OF THE YERKES OBSERVATORY BY G. W. RITCHEY.